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LONG-RANGE PLANS FOR ELECTRIFICATION AND DIESELIZATION OF RAILROADS IN THE USSR

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SECRET

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ECONOMIC INTELLIGENCE REPORT

LONG-RANGE PLANS FOR ELECTRIFICATION AND DIESELIZATION OF RAILROADS IN THE USSR

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(ORR Project 43.1605)

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FOREWORD

The USSR has included a major program for upgrading and modernizing its railroad system both in its original Sixth Five Year Plan announcements and in other announced long-range plan goals. Although this program entails many additions and improvements involving sizable capital outlays, nothing is of greater importance in the accomplishment of this objective than the conversion of primary motive power from steam to electric and diesel locomotives. This report analyzes the goals of this program, its progress, and its impact on the Soviet transport system and the Soviet economy and also contrasts the program with developments in motive power in the US.

On 25 September 1957 the USSR announced the necessity of drafting a new Seven Year Plan (1959-65). The drafting of this plan is to be completed by 1 July 1958. The new Seven Year Plan, however, is not expected to have a significant impact on the dieselization and electrification program -- these plans were made orginally on a long-term basis, and the entire program is mapped out in broad terms through 1970. In announcements as late as November 1957 the electrification goal for 1960 was restated by Soviet authorities. The meager information available on probable new transportation goals in the Seven Year Plan is pointed primarily at the need for construction of new lines into new producing areas, a factor which makes the dieselization and electrification programs even more imperative as the demands for rail transportation services increase. It is believed, therefore, that the long-range goal of complete electrification and dieselization by 1970 will stand, with the possible exception of short-term adjustments in the phasing of this program to put it in harmony with other goals of the new Seven Year Plan.

To facilitate discussion and analysis in this report, the original Sixth Five Year Plan period (1956-60) and the longer period (1961-70) are the two general time phases in which these programs are analyzed. This approach permits an accommodation of the evaluation and analysis to the format in which the Soviet data on these programs have been and are presently being reported.

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LONG-RANGE PLANS FOR ELECTRIFICATION AND DIESELIZATION OF RAILROADS IN THE USSR*

Summary and Conclusions

The USSR has undertaken a program of railroad electrification** and dieselization*** which is to replace steam locomotives completely by 1970. The results of the present dieselization and electrification program, even if the plans are not completely met, will be that the Soviet railroad system will be much closer to, and in some cases ahead of, US railroads in terms of modern, economical, and efficient transportation. Electrification and dieselization, with related improvements of auxiliary facilities, will permit Soviet railroads to handle existing traffic levels more efficiently and to carry increasing amounts of traffic without the necessity of making heavy investment in the installation of multiple tracks.

By the end of 1956, there were 6,325 kilometers (km) of electrified lines in the USSR and 7,000 km of dieselized lines. Electric and diesel locomotives together operated on 11 percent of the total railroad kilometrage and performed 17 percent of total railroad ton-kilometers (tkm).**** The estimated locomotive inventory at the end of

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* The estimates and conclusions contained in this report represent the best judgment of ORR as of 1 April 1958.

** The term electrification as used in this report denotes the installation of a trolley wire over a railroad track and the addition of the necessary auxiliary power facilities so that electric locomotives can operate on the track. Electrified railroad lines in the USSR have a single energized wire suspended over the track from concrete, metal, or wooden poles set on either side of the track. An electric locomotive collects current from the overhead wire by means of a pantograph and is operated by an electric motor attached to each axle.

*** The term dieselization as used in this report denotes the introduction of diesel-electric locomotives on a line and, usually, the removal of steam locomotives from the line. It involves installing diesel fuel facilities and rebuilding the repair facilities used by steam locomotives or building new repair facilities.

The term diesel locomotive as used in this report is an abbreviation of the term diesel-electric locomotive and is intended here to exclude diesel-mechanical locomotives. A diesel-electric locomotive consists of a diesel engine which operates an electric generator and thus produces power which is fed to electric traction motors, one on each axle.

**** Tonnages throughout this report are given in metric tons.

1956 included 1,363 electric, 1,050 diesel, and 31,880 steam locomotive units (freight, passenger, and switcher types). Until recent years, only small portions of either the annual or the 5-year plans for electrification were fulfilled. On the basis of performance in the past 2 years, however, it appears likely that the 1960 goal of electrifying 8,100 km of line will be fulfilled. Between 1961 and 1970, however, the USSR plans to electrify 32,000 km of line and to have a total of 45,500 km of electrified line in 1970, or 70 percent as much kilometrage as existed in the rest of the world in 1950. In view of its tremendous magnitude, it seems unlikely that the 1970 goal will be reached.

Lines operated by diesel traction are to increase from 6,400 km at the end of 1955 to 26,000 km by the end of 1960 and to an estimated length of 106,200 km in 1970.

In order to achieve the original 1960 Plan goals, the USSR has developed related plans for industry to produce 2,250 main-line, two-section diesel locomotives and at least 2,000 main-line electric locomotives during 1956-60. Plans for the production of diesel locomotives indicate that production will increase sharply into the period 1961-70, enabling the USSR to dieselize many of the lines which were to be electrified by 1970 but on which the high initial investment for electrification would be unjustified.

Railroad performance measured in ton-kilometers of freight is planned to increase by 42 percent between 1955 and 1960. Although it is planned to increase combined diesel and electric locomotive ton-kilometers by 335 percent by 1960, steam locomotives still will be carrying 57 percent of the total. The complete abandonment of steam operation by 1970, together with the estimated continuous increase in total traffic requirements, will require a sharp increase in the amount of traffic hauled per unit by diesel and electric locomotives, together with the planned increase in inventory of these types. This production per unit is likely to be attained, however, because of the superior operating efficiency of new diesel and electric traction, which permits the hauling of heavier trains with fewer servicing delays than is possible with steam locomotives.

During 1956-60, electrification and dieselization will consume from 27 to 30 percent of the total planned railroad investment of 70 billion rubles.* It is estimated that the total initial investment for electrification by the Ministry of Railroad Transportation in 1956-60, including related line improvements and locomotives, is to be 1.2 million

* For a discussion of ruble-dollar values, see IV, B, 3, p. 56, below.

to 1.5 million rubles per kilometer of primarily double-track line. Total cost of dieselization in 1956-60, including auxiliary facilities and locomotives, is estimated to be 407,350 rubles per kilometer of primarily single-track line. Dieselization of a double-track line, including the cost of locomotives, would probably cost about 700,000 rubles per kilometer.

Once the initial investment has been made, operating costs (including fuel, lubricants, and salaries of train crews) per gross ton-kilometer of freight traffic will be significantly lower with either electrification or dieselization. This lower cost will amortize the initial investment within a few years. It is estimated that total annual savings resulting from the replacement of steam operation by electric and diesel operation since 1955 amounted to 230 million rubles in 1956 and will rise to 5.25 billion rubles in 1960.

The Soviet conversion from steam to diesel and electric traction is to take place at a rate considerably slower than the US post-World War II conversion to diesel, in spite of the fact that average freight traffic density per kilometer of line in the USSR was 3.1 times that in the US in 1955.* In 1945, electric and diesel ton-kilometers represented 4.2 percent of total Soviet rail ton-kilometers and 8.9 percent of total US rail ton-kilometers. In 1955 the Soviet percentage had risen to only 14 percent, whereas in the US the figure had reached 87.5 percent.

Dieselization and electrification will have a significant impact not only on the railroads but also on the whole Soviet economy. It will be necessary for the USSR to invest in longer sidings and yard tracks, improved signaling and communications, new specialized repair facilities, and improved track to take full advantage of the efficiency potential of diesel and electric locomotives on many lines. On other lines the new locomotives may well postpone major investment in installing second tracks or centralized traffic-control signaling. The total locomotive inventory may be reduced slowly over the next decade as steam locomotives are retired and smaller numbers of more powerful and more efficient diesel and electric locomotives take their place. There is as yet no direct evidence that the USSR is scrapping steam locomotives and facilities for steam locomotives, although construction of steam locomotives ceased in 1956. As long as the steam locomotives and facilities are retained, there will be an impressive strategic reserve of motive power.

Introduction of the new motive power on lines formerly operated by steam will require a major retraining program in the operation and repair of these locomotives. The number of railroad employees per unit of

* See IV, B, 1, p. 50, below.

traffic, however, can be reduced because of the greater amount of traffic handled per worker by the modern types of motive power.

The impact of the dieselization and electrification program on the Soviet economy includes an increase in consumption of power for electric traction from about 2 percent of total Soviet production in 1955 to between 5 and 6 percent in 1970, an increase in consumption of diesel fuel from about 4 percent of total Soviet production in 1955 to an estimated 12 percent in 1960, and a decrease in consumption of coal from about 25 percent of total Soviet production in 1955 to an estimated 3 percent in 1970.

I. Introduction.

Following a moderate start in the Fourth and Fifth Five Year Plans (1946-50 and 1951-55) the USSR has embarked on a program, to be substantially completed by 1970, of electrifying a large portion of its total rail kilometrage and dieselizing the remainder. All steam motive power is to be retired. By 1970 the USSR plans to have as much elec trified railroad kilometrage as the present total for the remainder of the world. Locomotive construction and development and right-of-way improvement are planned to proceed simultaneously with the line conversion plan.

With more than a century of railroad operation behind it, the USSR in this program apparently has concluded that a much greater volume of freight and passengers can be moved more economically over its railroad system by paralleling methods and standards used in the US. Because of the high traffic density on many Soviet railroads, however, the USSR is pushing electrification more vigorously than dieselization, whereas in the US most railroad lines are dieselized and some electrification has been abandoned.

II. Background and Current Status.

By the end of 1956, electric and diesel locomotives operated on 11 percent (13,425 km) of the total railroad kilometrage in the USSR and performed 17 percent (185 billion tkm) of the total railroad ton-kilometers.

A. Electrification.

1. Kilometrage.

At the end of 1956, electrified railroad lines in the USSR totaled 6,325 km,* or 5.2 percent of the total railroad route kilometrage. Table 1** shows the total operational railroad kilometrage in the USSR, by type of motive power, for selected years, 1937-56, and for the 1957, 1960, and 1970 plans. These data are shown graphically in Figure 1.*** The overhead catenary system, even before the current Plans, had been installed on stretches of track that presented extreme operational difficulties and, in some cases, the greatest density of traffic, either freight or passenger. It was because of these operational difficulties and high traffic densities that the lines already electrified had been given priority in the electrification program.

The first electrification on Soviet railroads was completed in 1926 on a short suburban line from Baku northeast about 10 km to Sabunchi. 1/**** From this inconspicuous beginning the USSR has built up the longest total distance of electrified railroad lines in any country in the world. Except during World War II, the progress of electrification has been slow but steady since 1932, when several lines of industrial importance with severe gradient problems were electrified. One of these was the section of the Baku-Tbilisi-Kutaisi line from Khashuri (Stalinissi) to Zestafoni in Georgian ASSR, which has numerous 1.5-percent grades. Another was the Kizel-Chusovskaya-Sverdlovsk line in the Northern Urals over which ores were moved on a series of 1.78-percent grades. 2/ A total of 1,861 km of line was electrified before World War II (see Table 1).**

World War II caused a cessation of most electrification activities and partial destruction of some of the existing line. During the war, there was a net increase of 39 km, so that electrification totaled approximately 1,900 km by 1945. The Fourth Five Year Plan (1946-50) was to have added a total of 5,325 km of electrified lines. Actual additions, however, totaled approximately 1,185 km, sot

* Unless otherwise specified, line lengths in this report are given in terms of route kilometers rather than track kilometers. Route kilometers are the distance from one point to another on a line; track kilometers are the total length of tracks found between two points, including the yard tracks and the length of second track on double-track lines.

** Table 1 follows on p. 6.

*** Following p. 8.

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† Continued on p. 8.

Table 1

Total Operational Railroad Kilometrage in the USSR, by Type of Motive Power
Selected Years, 1937-57, and 1960 and 1970 Plans a/

End of Year	Total Operational Railroads (Kilometers)	Electrified Railroad		Dieselized Railroad		Steam-Operated Railroad	
		Kilometers	Percent of Total	Kilometers	Percent of Total	Kilometers	Percent of Total
1937	84,889 b/	1,632 c/	1.9 d/	N.A.	N.A.	N.A.	N.A.
1940	106,100 e/	1,861 f/	1.8 d/	229 g/	0.2	104,101 h/	98.0 i/
1945	112,868 b/	1,900 j/	1.6 d/	1,442 k/	1.3 l/	109,526 h/	97.1 i/
1950	116,900 e/	3,085 f/	2.6 d/	3,432 k/	2.9 l/	110,383 h/	94.5 i/
1951	117,761 e/	3,493 f/	3.0 d/	4,182 k/	3.6 l/	110,086 h/	93.4 i/
1952	118,563 e/	3,762 f/	3.1 d/	4,528 k/	3.8 l/	110,363 h/	93.1 i/
1953	119,943 e/	4,243 f/	3.5 d/	5,162 k/	4.3 l/	110,538 h/	92.2 i/
1954	120,300 e/	4,837 f/	4.0 d/	6,000 m/	5.0 n/	109,453 h/	91.0 i/
1955	120,700 e/	5,400 o/	4.5 d/	6,400 p/	5.3 l/	108,900 h/	90.2 i/
1956	120,700 q/	6,325 r/	5.2 d/	7,100 s/	5.9 l/	107,275 h/	88.9 i/
1957 plan	122,130 t/	7,588 u/	6.2 d/	9,065 v/	7.4 l/	105,477 h/	86.4 i/
1960 plan	127,200 w/	13,500 x/	10.6 d/	26,000 p/	20.4 l/	87,700 h/	69.0 i/
1970 plan	151,700 y/	45,500 z/	30.0 aa/	106,200 bb/	70.0 cc/	0	0 cc/

a. It is impossible to make most of these figures fully consistent with all Soviet sources, which disagree with each other on total kilometrage in any one year or on kilometrage added in any one year. This may be because some announcements are based on preliminary data released shortly after the year's end and because others are final figures. Some data probably represent line completed, and others may represent line accepted for operation by the Ministry of Railroad Transportation.
b. 3/
c. 4/
d. Percentages derived by dividing electrified route-kilometers by total route kilometers.
e. 5/

Table 1

Total Operational Railroad Kilometrage in the USSR, by Type of Motive Power
Selected Years, 1937-57, and 1960 and 1970 Plans
(Continued)

f. Derived from index numbers in 6/.
g. By the end of the Fourth Five Year Plan the length of lines transferred to diesel traction had increased 15 times compared with 1940. 7/ The figure for 1950 (3,432 km) was divided by 15 to derive diesel-operated kilometers for 1940.
h. Residual of the sum of electric plus diesel-operated kilometers subtracted from total kilometers.
i. Percentages are derived by dividing steam-operated kilometers by total kilometers.
j. 8/

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l. Percentages derived by dividing diesel-operated kilometers by total kilometers.
m. 10/
n. 11/. Year for which figure applies is not specified but is inferred.
o. 12/. This is a rounded figure; other sources suggest a figure as much as 100 km less.
p. 13/. It is believed that figures from this source are accurate, although rough figures of 7,000 km in 1955 and 25,000 km in 1960 are the ones usually cited by Soviet sources.
q. 14/. Source adds, "Not counting 600 km transferred to other organizations in 1956."
r. 15/. Another source gives 6,380 km, 16/ but the figure of 6,325 km seems more authoritative.
s. 17/
t. 18/. This report estimates the total planned net addition to operating line in 1957 at 1,430 km.
u. 19/. Plan calls for electrification of 1,263 km in 1957.
v. 20/. Plan calls for conversion of 1,965 km to diesel traction.
w. 21/
x. 22/
y. This estimate is based on the Soviet plan to have 45,500 km of electrified route in 1970, which is to be 30 percent of the total route length.
z. 23/
aa. 24/
bb. Derived by subtracting electrified kilometrage from total route length.
cc. Based on Soviet statement that 30 percent of route kilometrage will be electrified and on the plan to eliminate steam traction by 1970, 25/ the remainder to be dieselized.

that by 1950 electric traction was in operation on 3,085 km of line spread over 18 railroad systems. Elimination of the 1,032-km Karaganda-Akmolinsk-Kartaly line from the Fourth Five Year Plan, along with substantial underfulfillment on stretches of the Trans-Siberian, Trans-Caucasus, and Urals lines, helps to account for the completion of only 35 percent of the over-all electrification plan. 26/

The Fifth Five Year Plan (1951-55) called for the electrifying of 3,900 km of line.* 28/ At the end of the plan period the USSR announced a total construction of 2,267 km of electrified line. 29/ Total length of electrified line was therefore about 5,400 km by the end of 1955. During this plan period, there was emphasis on electrifying the Trans-Siberian, Trans-Caucasus, and Urals lines.** Figure 2*** shows the electrified and dieselized railroads in the USSR in 1955 and for the 1956-60 and 1961-70 plan periods.

Many excuses have been given for failure to complete planned kilometrage of electrified line. Some of the reasons enumerated in the Soviet press are failure to design or to produce adequate base posts for the catenary net, absence of adequate numbers and types of mercury rectifiers, inexperienced construction crews, and difficulties of weather and terrain. These excuses, however, undoubtedly were merely reflections of the urgent need for allocating material and labor resources to other sectors of the economy and the lack of a ready source of electricity. In some areas where catenary construction was being carried out, the coincident construction of electric power substations lagged so much that power was not available on the anticipated data. In 1955 this impediment was claimed to have been largely eliminated by the completion of electric power stations in areas servicing the lines scheduled for electrification under the original Sixth Five Year Plan (1956-60). In 1956 it was reported that substations were completed in some sections but that the power transmission lines (apparently from powerplant to substation) had not been completed. Although electric locomotive construction also fell short of plan, there is no evidence that a shortage of electric locomotives prevented the operation of lines on which the catenary had been completed. In fact, on a number of lines new electric locomotives were placed in storage until the poles and catenary were installed. 30/

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* The original plan announcement called for electrifying about four times the kilometrage accomplished in the Fourth Five Year Plan, 27/ which would be about 4,700 km. This announcement may refer to track kilometers, however, rather than to route kilometers.

** Railroad electrification in the USSR as of 31 December 1955 and future plans are shown in Appendix A.

*** Inside back cover.

Figure 1

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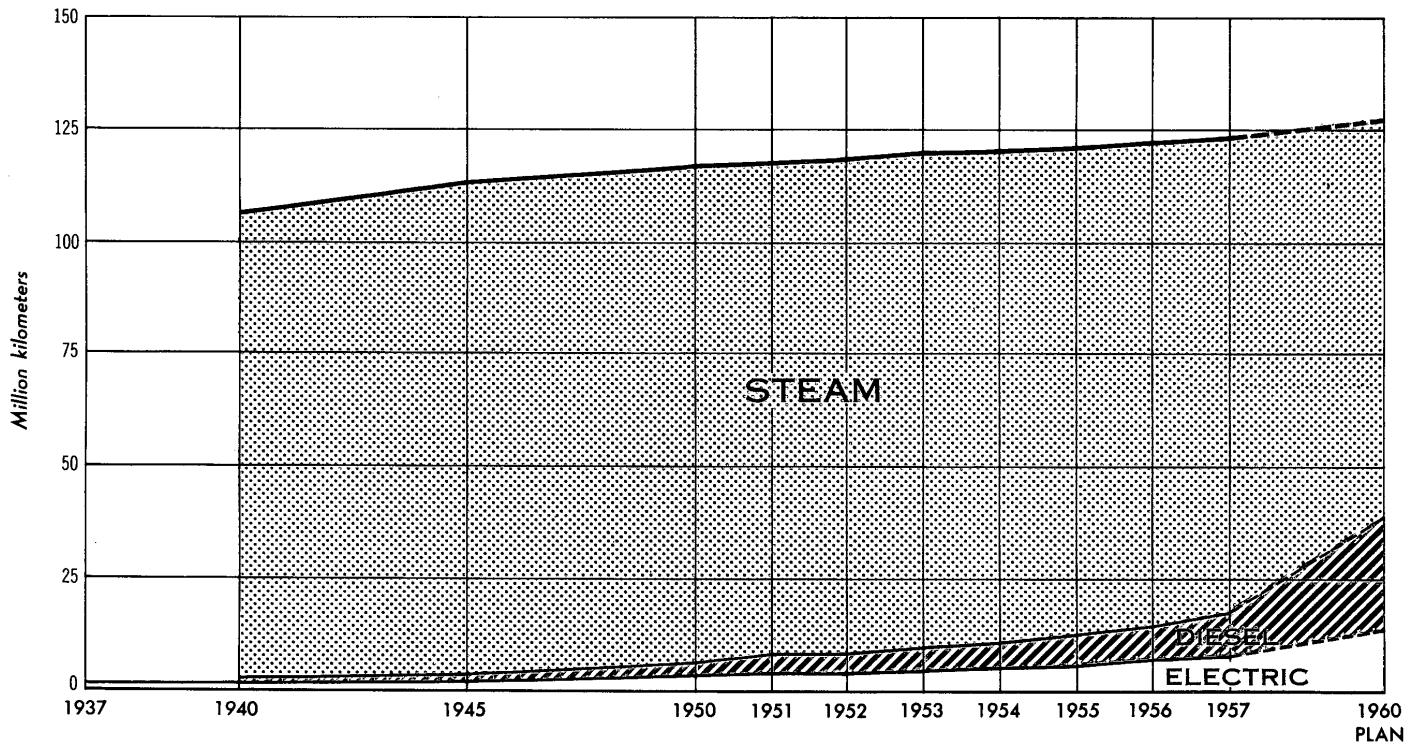
LENGTH OF RAILROAD LINES WITH STEAM, ELECTRIC, AND DIESEL OPERATION SELECTED YEARS, 1937-57 AND 1960 PLAN



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2. Performance.

In 1956, electric locomotives in the USSR performed 111.1 billion tkm, or 10.3 percent of the total of 1,079.1 billion tkm performed by all Soviet railroads. Electric locomotives have hauled a consistently increasing share of total rail traffic since 1940, when they performed 10 billion tkm, or 2.4 percent of the total. Table 2* shows the total rail freight traffic performed in the USSR, by type of motive power, for selected years, 1940-57, and for the 1960, 1965, and 1970 plans. These data are also shown graphically in Figure 3.**

3. Inventory.

Estimates of cumulative production of main-line electric locomotives in the USSR from 1932 through 1956 total 1,393 units. In addition, 15 units were imported from 1932 through 1934, making a total of 1,408 units. Many of the electric locomotives produced or imported in prewar years are still in use. It is also estimated that retirements between 1931 and 1956 totaled only about 45 units,*** which, subtracted from total acquisitions of 1,408 units, leaves an estimated total inventory of main-line electric locomotives of 1,363 units on 31 December 1956. By contrast, the inventory of steam locomotives at the end of 1956 is estimated at 31,880 units (freight, passenger, and switcher types). 31/ Table 3**** shows estimated production and imports of main-line electric locomotives by year from 1932 through 1956.†

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* Table 2 follows on p. 10.

** Following p. 10.

*** It is estimated that 15 locomotives representing approximately one-fourth of the nonstandard series (such as Ss, SK, and SM) have been retired. It is estimated that retirements of the standard series (VL-19, VL-22, and VL-22m) have been very low and have probably been limited to units involved in wrecks and fires. On this basis, retirements of standard electric locomotives are estimated at approximately 30. No account could be taken in this estimate of war losses or of war booty.

**** Table 3 follows on p. 11.

† Basic characteristics, estimated total production through 1956 by major types of electric and diesel locomotives used in the USSR, and photographs of these locomotives are shown in Appendix B. There is evidence that during the postwar period the USSR has imported electric locomotives from other countries and that it has attempted to acquire additional ones. These locomotives, however, apparently were all for industrial use and will not be considered in this report. (Text continued on p. 12.)

Table 2

Total Railroad Freight Traffic in the USSR, by Type of Motive Power
Selected Years, 1940-57, and 1960, 1965, and 1970 Plans

	Billion Ton-Kilometers				Percentage Distribution			
Year	Total	Steam [a]	Electric [a]	Diesel [a]	Total	Steam	Electric	Diesel
1940	415.0 [b]	404.2	10.0	0.8	100	97.4 [c]	2.4 [c]	0.2 [c]
1950	602.3 [b]	567.4	21.7	13.2	100	94.2 [c]	3.6 [c]	2.2 [c]
1954	856.8 [b]	769.4	54.0	33.4	100	89.8 [d]	6.3	3.9 [d]
1955	970.9 [b]	835.0	82.5	53.4	100	86.0 [c]	8.5 [c]	5.5 [c]
1956	1,079.1 [e]	893.5	111.1	74.5	100	82.8	10.3 [e]	6.9 [e]
1957	1,209.0 [f]	967.2	145.1 [g]	96.7 [g]	100	80.0	12.0 [g]	8.0 [g]
1960 plan	1,374.0 [h]	783.0	289.0	302.0	100	57.0 [c]	21.0 [c]	22.0 [c]
1965 plan	1,818 [i]	273.0	781.5	763.5	100	15.0 [c]	43.0 [c]	42.0 [c]
1970 plan	2,305 [i]	0	1,267.8	1,037.2	100	0	55.0 [c]	45.0 [c]

a. Computed from corresponding percentage data.
b. 32/
c. 33/
d. 34/
e. 35/
f. 36/
g. 37/. This source shows that 20 percent of total ton-kilometers were performed by diesel and electric locomotives combined. This is 241.8 billion tkm, which was distributed between electric and diesel by interpolation between figures for 1954-56 and for 1960.
h. 38/. 1956 and 1957 overfulfillment, largely due to increased average length of haul in spite of planned decreases, indicates probably overfulfillment of the 1960 plan to an estimated 1,595 billion tkm.
i. Estimated; projections based on absolute increase -- 1955 above 1950, and 1960 above 1955.

Figure 50X1

USSR

TON-KILOMETERS PERFORMED BY STEAM, ELECTRIC, AND DIESEL LOCOMOTIVES SELECTED YEARS, 1940-56, AND 1957 AND 1960 PLANS

(Billion ton-kilometers)

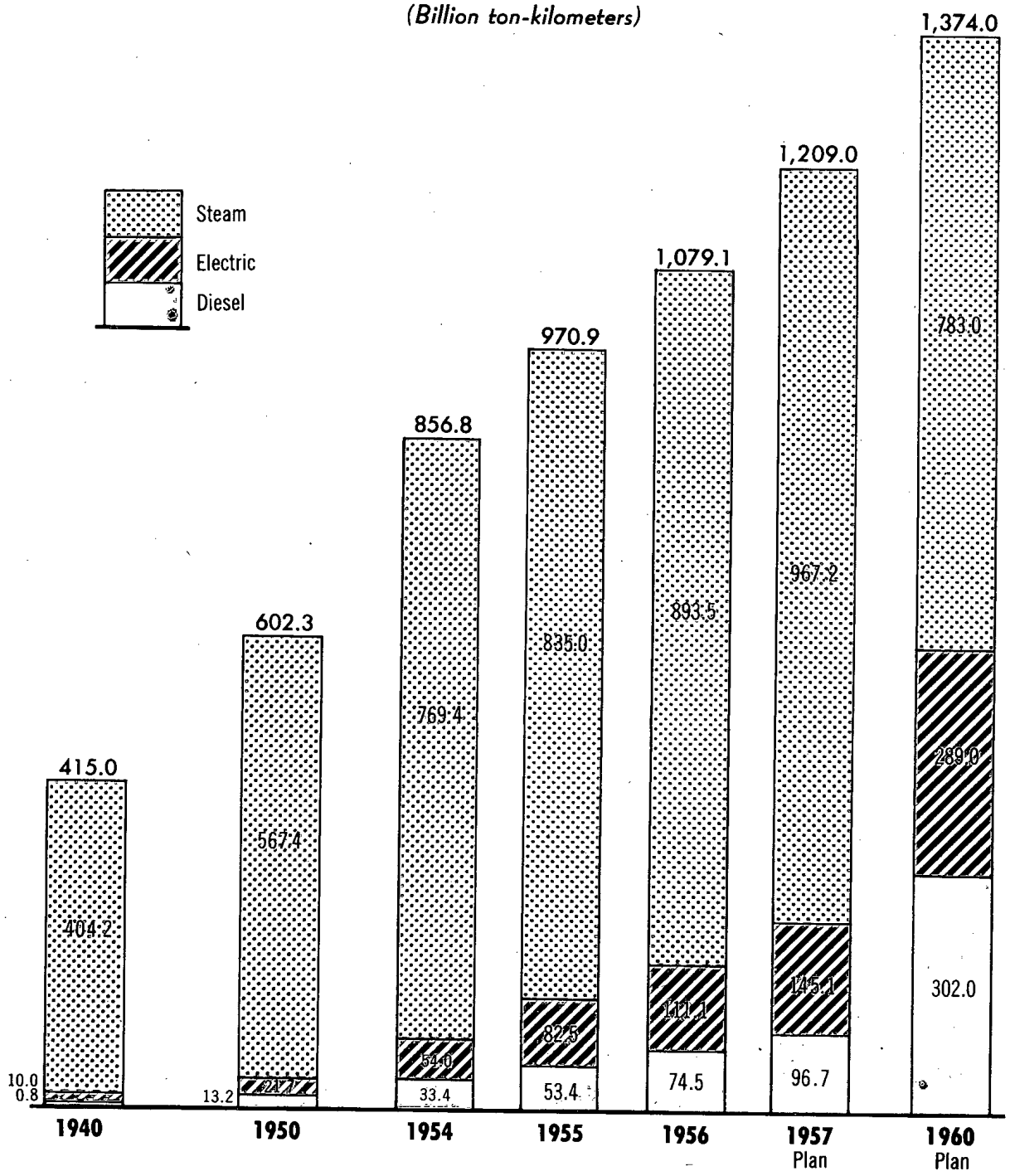

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Table 3

Production and Imports of Electric Main-Line Locomotives by the USSR
1932-56

Units

Year	Production [a]	Imports [b]
1932	3	8
1933	17 [c]	3
1934	19 [c]	4
1935	34	0
1936	46	0
1937	32	0
1938	32	0
1939	17	0
1940	9	0
1941	7 [d]	0
1942-45	0	0
1946	1	0
1947	16	0
1948	38	0
1949	82	0
1950	102	0
1951	113	0
1952	110	0
1953	147	0
1954	158	0
1955	194	0
1956	216	0
Total	1,393	15

a. 39/. Except for 1941 figure.
b. 40/. The 8 were S series from the US; the 7 were Si series from Italy.
c. Twenty-one of these were Ss series assembled from parts imported from the US. 41/
d. Estimate.

4. Investment.

Electrification of railroads demands large initial investment outlays which are expected to yield greatly increased railroad efficiency and reduced operating costs. Soviet engineers and planners claim that these benefits create operating savings which amortize the initial investment in 3 to 10 years. Estimated investment in electrified lines and electric locomotives in the USSR for the periods 1926-45, 1946-50, 1951-55, 1956-60, and 1961-70 are shown in Table 4.*

Total investment in electrified lines and locomotives during 1926-55 is estimated to be 7,512 million 1955 rubles. The estimated average total investment per kilometer of line electrified has been rising, from 1,215,000 1955 rubles in the 1926-45 period to 1,552,000 rubles in the 1951-55 period. This increase reflects the fact that electrification is being installed on steam-operated lines which have reached relatively high freight as well as passenger traffic densities. Earlier electrifications were cheaper partly because some of the lines -- in the Moscow area, for example -- were electrified only to carry suburban passenger traffic while freight continued to be moved by steam locomotives.

B. Dieselization.

1. Kilometrage.

The first Soviet diesel-electric locomotive was put into operation in 1924. 42/ Although the advantages of this type of traction were widely discussed at that time, diesels were not used extensively in the USSR until after World War II. In 1940, only 229 km of railroads were considered to be dieselized (see Table 1, p. 6, above). Introduction of diesels on the Ashkhabad Railway in Turkmen SSR in 1932 was the first general attempt to use this type of traction on a system basis. 43/ This railroad system has long stretches of single-track line of medium freight density crossing arid plains. With its only occasional need for water and its relatively light fuel requirement, the diesel locomotive could go for long distances across the plains without having to stop for servicing.

By the end of the Fifth Five Year Plan (1951-55) the USSR had a total of 6,400 km of diesel-operated line (see Table 1, p. 6, above). In 1955, there was a total of 6,400 km of dieselized lines compared with 5,400 km of electrical lines. A large part of the electrified line was double track, however, with high traffic density, whereas the

* Table 4 follows on p. 13.

Table 4

Estimated Investment in Electrified Lines and Electric Locomotives in the USSR for the Periods 1926-45, 1946-50, 1951-55, 1956-60, and 1961-70

	Electrified Lines			Electric Locomotives			Electrified Lines and Locomotives	
Period	Line Electrified a/ (Kilometers)	Estimated Investment b/ (Million 1955 Rubles)	Estimated Average Cost per Kilometer b/c/ (1955 Rubles)	Number Produced and Imported d/	Estimated Investment e/ (Million 1955 Rubles)	Estimated Average Cost of Equipment per Kilometer (1955 Rubles)	Total Investment (Million 1955 Rubles)	Average Total Investment per Kilometer (1955 Rubles)
1926-45	1,900	1,900	1,000,000	231	409	215,000	2,309	1,215,000
1946-50 (Fourth Five Year Plan)	1,185	1,185	1,000,000	239	424	358,000	1,609	1,358,000
1951-55 (Fifth Five Year Plan)	2,315	2,315 f/	1,000,000	722	1,279	552,000	3,594	1,552,000
Total through 1955	5,400 5,400	5,400	1,000,000	1,192	2,112	391,000	7,512	1,391,000
1956-60	8,100	6,456 to 8,456 g/	797,000 to 1,044,000 h/	2,000 i/	3,544	438,000	10,000 to 12,000 j/	1,233,000 to 1,480,000
1961-70	32,000	32,000 k/	1,000,000	N.A.	N.A.	N.A.	N.A.	N.A.

a. From Table 1, p. 6, above.
b. Derived by multiplying total line electrified by estimated average cost per kilometer. Including investment in expansion of capacity of electric power stations; construction of electric power transmission lines, overhead power lines above the track, and transformer stations 44/; and related improvement of signaling, communications, and personnel-housing facilities. It is not clear whether only power stations and transmission lines of the Ministry of Railroads are included or whether a proportionate share of the facilities of the Ministry of Electric Power is also included.

Table 4

Estimated Investment in Electrified Lines and Electric Locomotives in the USSR for the Periods 1926-45, 1946-50, 1951-55, 1956-60, and 1961-70
(Continued)

c. The averages shown in this column may be compared with the Gosstroy (State Construction Administration) standard costs for electrifying 1 kilometer of operating rail line 45/: single-track main line, 350,000 rubles; double-track main line, 500,000; single-track suburban line, 530,000; double-track suburban line, 1 million. Another Soviet statement estimated the full costs of electrification (apparently including electric locomotives) to be as high as 1 million rubles per kilometer, presumably in 1955. 46/ Another Soviet source shows a total expenditure for stationary installations only (including expansion of power stations and construction of high-voltage transmission line) of 1.1 million rubles per kilometer of single-track line and 1.5 million rubles per kilometer of double-track line. 47/ Although it is difficult to set an accurate 1955 price, an estimated average of 1 million rubles per kilometer is believed to be reasonable.
d. Not including the cost of multiple-unit suburban passenger equipment used on electrified railroads in the vicinity of large cities.
e. Based on an estimated average cost per unit of 1,772,000 rubles.
f. 48/. Source shows that 381 million rubles of this amount were spent in 1955.
g. Calculated by subtracting the estimated 3,544-million-ruble investment in electric locomotives from the announced total investment for electrification of 10 billion to 12 billion rubles.
h. Derived by dividing estimated investment by total line electrified.
i. "At least 2,000 electric locomotives" are to be produced in the Sixth Five Year Plan period. 49/
j. 50/
k. Based on a statement by the Deputy Chief of Main Administration of Electrification and Power Economy of the Ministry of Railroads that the general transport electrification plan (for electrifying 40,000 km in the 15-year period 1956-70) will require a capital investment of more than 30 billion rubles. 51/ It is believed that this excludes the cost of electric locomotives because this figure would average 750,000 rubles per kilometer.

dieselized lines were primarily single track and of low traffic density. Because of inherent operating advantages in waterless areas, diesels were first utilized in Turkmen, Tadzhik, Uzbek, and Kazakh SSR's; in the Trans-Volga area; and in the Caucasus.

2. Performance.

Diesel locomotives performed less than 1 percent of the total ton-kilometers of Soviet railroads in 1940 and by 1950 had increased their share to only 2.2 percent (see Table 2, p. 10, above). In 1955, at the end of the Fifth Five Year Plan, they were performing only 5.5 percent of total ton-kilometers.

3. Inventory.

Production of diesel locomotives from 1924 through 1956 totaled 1,063 units, and imports totaled 108 units. Net acquisitions were therefore 1,171 units. Of this total, it is estimated that 121 units were retired or otherwise deducted from total inventory.* The inventory of main-line diesel locomotives at the end of 1956 is therefore estimated at 1,050 diesel units. Table 5** shows estimated production and imports of main-line diesel locomotives by the USSR for 1924-26 and 1930-56.

* It is believed that the 96 locomotives imported from the US during World War II were converted into TE-1 and TE-2 locomotives and were thus included in Soviet production figures (the 66 type Da diesels imported from the US were probably converted to 66 type TE-1 locomotives, and the 30 single-unit type Db diesels imported from the US probably converted to 15 2-unit type TE-2 locomotives). It is estimated that of the remaining 1,075 locomotives (1,063 produced plus 12 imported), there were only about 25 units retired. Of the 55 units produced and imported in prewar years (primarily the EEL and OEL types), it is estimated that one-fifth, or 11 units, were retired, leaving 44 in operation. Of the 1,014 units produced from 1947 to 1956 (primarily TE-1, TE-2 and TE-3 types), it is estimated that only about 14 have been retired, leaving about 1,000 in operation.

50X1
50X1

** Table 5 follows on p. 16.

Table 5

Production and Imports of Main-Line Diesel Locomotives by the USSR a/*
1924-26 and 1930-56

Units b/

Year	Production	Imports
1924	1 c/	1
1925	0	3
1926	0	1
1930	0	0
1931	2	0
1932	1	1
1933	1	0
1934	8	0
1935	4	0
1936	13	0
1937	4	0
1938	4	0
1939	6	0
1940	5	0
1941	0	0
1942	0	0
1943	0	0
1944	0	66 d/ e/
1945	0	30 e/
1946	0	0
1947	25	0
1948	69	6 f/
1949	128	0
1950	125	0
1951	76	0
1952	75	0
1953	101	0
1954	120	0
1955	134	0
1956	161	0
Total	1,063 g/	108

* Footnotes for Table 5 follow on p. 17.

Table 5

Production and Imports of Main-Line Diesel Locomotives by the USSR a/ 1924-26 and 1930-56 (Continued)

a. Source 53/ except where otherwise indicated.
b. Postwar production of TE-2 diesel-electric locomotives is stated in terms of two-unit locomotives; TE-3 production, which began in 1953, is in terms of single units.
c. Estimated.
d. Seventy were exported, but four were lost en route.
e. It is believed that these locomotives were given a Soviet designation and were also included in production figures in later years (see footnote, p. 15, above).
f. Year of import not certain.
g. This production total is believed to include the 96 locomotives also shown as imported from the US

[redacted] 50X1

4. Investment.

No announced figures are available on annual or 5-year plans for investment to be made in dieselizing railroads. Investment in dieselization has received less attention in Soviet publications than has investment in electrification. On the basis of Soviet sources, an average figure of 40,000 rubles per kilometer for permanent installations is used in this report. The major portion of such investment is probably expended on establishing diesel repair and servicing (such as fueling) facilities. It is possible that it also includes the cost of lengthening siding and yard tracks so that the longer trains, which can be pulled by diesel locomotives, can be accommodated.

The estimated investment for dieselization in the USSR, including line facilities and locomotives, for 1924-55 and the 1956-60 plan is shown in Table 6.* Total investment for 1924-55 is estimated at 1,805 million 1955 rubles. The average total investment per kilometer of

* Table 6 follows on p. 19.

dieselized line jumped from an estimated 78,400 1955 rubles in 1924-45 to 401,000 rubles in 1956-60. The small investment per kilometer in 1924-45 was caused by the fact that diesels were installed primarily on single-track lines which did not have high traffic density and therefore required a comparatively small investment in ancillary facilities and only a small number of diesel locomotives per kilometer of line.

The cost of diesel locomotives represents a very high percentage of the total investment required to dieselize a railroad line. It is estimated that during 1924-45 locomotives represented about 50 percent of total investment for dieselization. In the Fifth Five Year Plan and later planning periods, diesel locomotives represent 90 percent of the total investment. By contrast, electric locomotives represent less than half the total investment required to electrify a line, although the price per unit is roughly equal to the average price per diesel unit (see Table 4, p. 13, above).

III. Summary of Long-Range Plans and Progress.

A. Plans for Electrification.

1. 1956-60 Plan.

Announced Soviet plans for 1960 call for the electrification of 8,100 km of route, which will increase the total length of electrified stretches to 13,500 km at the end of 1960 (see Table 1, p. 6, above). This figure apparently does not include the Dudinka-Noril'sk line (about 100 km), which is not yet included in the total kilometrage 54/ but which has been in operation and is to be electrified in the present plan period. 55/

Most of the 8,100 km to be electrified will be supplied with the standard 3,000 volts direct current (DC), but the USSR hopes to equip about 2,500 km initially with an alternating current (AC) system and a new type of AC locomotive.* 56/ The latter kilometrage includes not only the Ozherel'ye-Pavelets line running southeast of Moscow but also the 1,341-km Mariinsk-Cheremkhovo section of the Trans-Siberian Railroad.** 57/ The adjoining sections of the Trans-Siberian from Novosibirsk to Mariinsk and from Cheremkhovo to Irkutsk will operate, for the time being at any rate, on DC. 58/

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* For a discussion of the relative merits of AC and DC electrification, see Appendix C.

** See Figure 2, inside back cover.

Table 6

Estimated Investment in Line Facilities and Diesel Locomotives
for the Dieselization Program in the USSR
1924-55 and 1956-60 Plan

	Diesel Line Facilities		Diesel Locomotives			Diesel Facilities and Locomotives	
Period	Total Length of Line a/ (Kilometers)	Estimated Investment b/ (Million 1955 Rubles)	Number Produced or Imported (Units)	Estimated Average Price per Unit (1955 Rubles)	Estimated Investment (Million 1955 Rubles)	Total Investment (Million 1955 Rubles)	Average Total Investment per Kilometer of Line (1955 Rubles)
1924-45	1,442	58	55 c/	1,000,000 d/	55	113	78,400
1946-50 (Fourth Five Year Plan)	1,990	80	6 e/	1,000,000 d/	6		
			301 TE-1 f/	1,060,000 g/	319		
			46 TE-2 h/	2,120,000 f/	97		
Total					422	502	252,000
1951-55 (Fifth Five Year Plan)	2,968	119	501 TE-2 h/	2,120,000 i/	1,062		
			4 TE-3 j/	1,600,000 k/	6		
			1 TE-4 l/	2,600,000 m/	3		
Total					1,071	1,190	401,000
Total through 1955	6,400	257			1,548	1,805	282,000
1956-60	19,600	784	4,500 n/	1,600,000 o/	7,200	7,984 p/	407,000 p/

a. See Table 1, p. 6, above.
b. Estimated at 40,000 rubles per kilometer of line, based on a Soviet statement showing a cost of 30,000 to 40,000 rubles per kilometer of line. 59/ Most dieselized lines are single track. The higher figure is used to take into account the dieselization of some double-track lines.
c. See Table 5, p. 16, above. Including production, which consisted of the following types: Shchel, OEL, EEL, and VM-20, and all imports, except for the 96 imported from the US which were believed to be converted to TE-1 and TE-2 types.

Table 6

Estimated Investment in Line Facilities and Diesel Locomotives
for the Dieselization Program in the USSR
1924-55 and 1956-60 Plan
(Continued)

d. Estimated.
e. See Table 5, p. 16, above. Imported locomotives.
f. See Table 8, p. 30, below. The TE-1 locomotives were produced from 1947 through 1950.
g. Based on the 1955 price per horsepower of the TE-3.
h. Of the 548 TE-2 locomotives (each composed of 2 units) produced, as shown in Table 8, p. 30, below, it is estimated that 46 were produced in 1949 and 1950 and the remainder from 1951 through 1955. Of the latter, one unit was converted to the TE-4.
i. 60/. Price quoted is 1,060,000 rubles for a single unit of a TE-2, or 2,120,000 rubles for a 2-unit TE-2 locomotive. The former price is compatible with a price of 1,040,000 rubles for 1 section of a TE-2 locomotive as given in an official Soviet price handbook. 61/
j. Estimated.
k. 62/. At 1,600,000 rubles for a 1-unit 2,000 hp TE-3 and 1,060,000 rubles for 1 unit of a TE-2, the TE-3 would be 25 percent cheaper per horsepower than the TE-2.
l. This locomotive was made up of two TE-2 units, with a gas generator unit between.
m. Estimated on the basis of the TE-2 price, plus estimated cost of a gas generator unit.
n. 63/. By 1960 the USSR planned to produce 2,250 main-line, 2-section diesel locomotives, or 4,500 individual units. Many of these will be TE-3 units, and some will be TE-7, which is a modification of the TE-3 for passenger and express train service.
o. Estimated on the basis of the price of the TE-3 diesel.
p. Imports of diesel locomotives plus domestic production of diesel-mechanical standard-gauge switchers and narrow-gauge diesel locomotives will raise these figures to an estimated total of 9 billion rubles, or an average cost per kilometer of 459,000 rubles.

a. Trans-Siberian Railroad.

Electrification of the country's principal east-west railroad, the Trans-Siberian, between Moscow and Vladivostok (9,447 km via Kuybyshev), is to be completed from Moscow to Slyudyanka (5,446 km) on Lake Baykal by 1960, via Kuybyshev, Chelyabinsk, Omsk, and Novosibirsk. The target date for electrification of the entire line to Vladivostok is 1965. By the end of 1955, 1,444 km of this route had been electrified (see Appendix A). 64/ A recent radiobroadcast stated that electrification of the stretch of the Trans-Siberian line between Ulan-Ude and Petrovskiy Zavod would begin shortly, presumably in 1957. 65/ This is the first indication of plans for electrification of the Trans-Siberian east of Slyudyanka before 1960. Steep grades and fairly heavy traffic on this 143-km section, as well as the existence of a large powerplant in the Ulan-Ude section, make plans for its early electrification plausible.

The Inskaya-Belovo stretch of the Trans-Siberian branch line to the Kuznetsk Coal Basin is to be electrified during this 1956-60 period. The 19 km between Novosibirsk and Inskaya and the 141 km from Belovo to Novokuznetsk (Stalinsk) were previously converted to electric traction.

Although not listed in early reports of railroads to be electrified, a branch of the Trans-Siberian Railroad from Omsk to Nazyvayevskaya on the Omsk-Tyumen-Sverdlovsk line was included in plans for 1956, and electrification was completed in 1956.

b. Urals.

Announced Soviet plans called for the immediate electrification of two important new lines in the Urals, whose construction is to be completed by 1960. One from Kizel to Perm' (Molotov) is to cut the rail haul of Kizel coal to Molotov and points beyond by more than 80 km. The other, from Magnitogorsk through the Urals to Abdulino, a distance of 540 km, is the last stretch on the western end of the South Siberian Railroad. It will substantially reduce the rail distances between the important Urals metallurgical center of Magnitogorsk, the Ishimbay oilfield, and more distant points in the European USSR. 66/ The existing 252-km north-south rail route between Sverdlovsk and Chelyabinsk will also be electrified, 67/ thus bridging the gap in electric traction between the electrified networks of the Northern Urals and railroads serving the important mineral and industrial centers in the Southern Urals and Northern Kazakhstan.

c. Donets Basin.

The line running from the Donets Coal Basin through Khar'kov to Moscow is to be electrified by 1960. This line carries heavy coal traffic from the country's most important coal basin principally to the Moscow industrial area.

It was recently announced that electrification of another important Donets Basin line, the 174-km stretch from Bataysk to Likhaya on the rail route between Moscow and the Caucasus via Voronezh, would be carried out in 1958. 68/ This stretch passes through Rostov-on-Don and serves mines in the vicinity of Shakhty.

Electrification of the Yasinovataya-Pyatikhatki line between the Donets Coal Basin and the Krivoy Rog metallurgical industry is also to be completed by 1960.

d. Moscow Area Lines.

Considerable electrification of suburban lines emanating from Moscow is anticipated during 1956-60. The planned increase of electrified lines in the Moscow area during the period has been reported variously as 700 km, 69/ 880 km, 70/ and 1,000 km. 71/ These various distances may indicate either a lack of a final decision on priorities or the inclusion or omission either of the Moscow terminal distances of through routes or of the Moscow and Leningrad subway system.

On the main Moscow-Leningrad railroad the Klin-Kalinin stretch is to be electrified by 1960 so that electric locomotives will be able to operate all the way from Moscow to Kalinin (167 km). One Soviet rail magazine reports that electrification will be completed by 1960 from Leningrad to Malaya-Vishera (162 km). 72/ A rough map in a Soviet newspaper confirms electrification plans for a section extending from Leningrad approximately to this point. 73/ Another map, however, does not show it, 74/ and a third map shows that dieselization is planned for the whole section from Tosno to Kalinin. 75/ Therefore, it appears that if the entire Moscow-Leningrad line is to be electrified, it will take place after 1960, before which time the line will be operated for a number of years with diesel locomotives.

Electrification of the 52 km between Mikhaylov and Pavelets, which is the second section of an experimental AC line which will extend from Ozherel'ye to Pavelets (137 km), is also planned. The first section from Ozherel'ye (124 km southeast of Moscow) to Mikhaylov was wired in 1955 and at present is being used for the testing of new types of AC locomotives.

Other Moscow area lines to be electrified by 1960 are Aleksandrov-Vspol'ye, Zheleznodorozhnaya-Fryazevo-Noginsk, Iksha-Dmitrov, Lyubertsy-Kurovskaya-Cherusty, Golitsyno-Mozhaysk, Aprelevka-Maloyaroslavets, and Novoiyerusalimskaya-Volokamsk.

e. Murmansk Line.

There is some question of what electrification is planned on the Leningrad-Murmansk line. The single-track section between Kandalaksha and Murmansk (278 km) has been operated by electricity for a number of years, the original objective having been to minimize difficulties of cold weather. According to present plans, 76/ the railroad from Sorokskaya to Apatity (484 km) is to be double tracked. Of this distance, 94 km are north of Kandalaksha, and this portion of the new double track presumably will be electrified. One Soviet source reports that the line is to be electrified from Kandalaksha as far south as Loukhi (167 km) in 1958, 77/ but none of the Soviet maps of lines to be electrified by 1960 includes this stretch, and several other sources report that the section is to be dieselized during this period. 78/ Reasons for the double tracking and priority changeover of motive power on this line, in addition to cold weather, appear to include a planned doubling of the traffic, particularly of northbound timber and building materials and of southbound metallic ores and phosphate rock (apatite). 79/ Density of freight traffic on the electrified section between Kandalaksha and Murmansk is reported to have reached 5 million tkm per kilometer in 1954 80/ compared with the national average density of 7 million tkm per kilometer. 81/

f. Caucasus Line.

Electrification of the Sukhumi-Sochi-Belorechenskaya line (347 km) along the eastern shore of the Black Sea is scheduled for completion by 1960. This line is an extension of the previously electrified Akstafa-Tbilisi-Sukhumi section.

g. Other Suburban Lines.

Electrification is planned by 1960 of a number of suburban lines, not all precisely identified, radiating from Baku, Kiev, Khar'kov, and Stalingrad. 82/

2. Progress in 1956.

In 1956 it was planned to electrify 847 km of railroad, or 981 km if the Irkutsk-Slyudyanka section which was completed in 1955 83/ but not put in operation until April 1956 is included. 84/ Actually a total of 969 km of electrified line was put in operation in 1956. Table 7* shows railroad lines electrified in the USSR in 1956 and those to be electrified in 1957.**

* Table 7 follows on p. 24.
** Continued on p. 26.

Table 7

Additions to the Soviet Electrified Rail Network
1956 and 1957 Plan

Kilometers

Lines Electrified During 1956 a/*	Length b/	Lines Planned for Electrification During 1957	Length b/
Trans-Siberian Main Line (including European section)			
		Syzran'-Kuybyshev c/	136
Dema-Rayevka	105	Pokhvistnevo-Rayevka c/	250
Kurgan-Makushino	131	Chelyabinsk-Kurgan c/	257
Branch Lines of Trans-Siberian			
Omsk-Nazyvayevskaya	149	Belovo-Promyshlennaya c/	86
Other Main Lines to the East			
		Zheleznodorozhnaya-Noginsk c/	44
Ural Lines Not Included Elsewhere			
Kizel-Perm' (Molotov)	160 d/		
Moscow-Khar'kov-Donbass			
		Serpukhov-Skuratovo c/	185
		Khar'kov-Merefa	22
Other Moscow-Donbass-Caucasus Connections			
Mikhaylov-Pavelets	52		
Caucasus Lines			
		Tuapse-Belorechenskaya c/	126
Sukhumi-Sochi	139	Zestafoni-Chiatura (new line)	36 e/

* Footnotes for Table 7 follow on p. 25.

Table 7

Additions to the Soviet Electrified Rail Network
1956 and 1957 Plan
(Continued)

Kilometers

Lines Electrified During 1956 a/	Length b/	Lines Planned for Electrification During 1957	Length b/
Other Moscow and Leningrad Area Lines			
Iksha-Dmitrov	20	Klin-Kalinin c/	78
Carpathian Lines			
Mukachevo-Lavochne	79		
Total	835 f/		1,220 g/

a. 85/
b. Distances from official passenger timetable 86/ unless otherwise noted.
c. 87/
d. 88/
e. 89/
f. Irkutsk-Slyudyanka section (134 km) has been excluded because it has been counted with lines in 1955. With the addition of this line, the 1956 total is 969 km.
g. This total does not agree precisely with the 1957 plan to put 1,263 km of electrified line 90/ in operation, perhaps because of variations in length of line as shown in various Soviet official sources. Plan fulfillment data for 1957, received after compilation of this report, shows that the goal for total completions was fulfilled.

On the basis of 981 km scheduled for electrification in 1956, it can be computed that the plan for putting electrified stretches in operation was 99 percent fulfilled. This is a considerable improvement over 1955, when 490.5 km, or 63 percent of the plan, were put in operation. 91/ (Table 1, p. 6, above, shows a 553-km increase in 1955 because the figure for 1955 is rounded.) Nevertheless, performance in 1956 in other aspects of rail electrification has been adversely criticized in the Soviet press. One article pointed out that the plan for preparatory work during 1956 for 1957 electrification projects was fulfilled by only 77 percent. It was stated that plans for the manufacture and installation of concrete supports were not being fulfilled and that less than half the planned number of concrete supports were set up. The process of digging excavations for supports, which accounts for more than half the labor expended in construction of an overhead contact network, was still being performed by hand, and other time-consuming methods were also being used. Although a promising new pile-driving machine was being tested, the first dozen will apparently not be available until 1958. 92/

3. Plans for 1957.

During 1957, 1,263 km of electrified lines were planned to be put in operation 93/ (see Tables 1, p. 6, and 7, p. 24, above). The major portion of this was to be composed of three sections on the Moscow-Kuybyshev-Omsk line: Syzran'-Kuybyshev, Pokhvistnevo-Rayevka, and Chelyabinsk-Kurgan. 94/ Together, they totaled 643 km, or about half the lines scheduled for electrification in 1957.

Several other stretches have also been reported as scheduled for electrification in 1957. One is the 86-km Promyshlennaya-Belovo section 95/ of the Kuznetsk Basin branch line of the Trans-Siberian. A second is the 78-km Klin-Kalinin 96/ section, on the main Moscow-Leningrad route. In addition, the recently completed 36-km line from Zestafoni to Chiatura, a manganese center in the Caucasus, will be converted to electric traction in 1957. 97/ This new line runs parallel to the old narrow-gauge line from Shorapani to Chiatura. Regular traffic on the new line began in September 1956. 98/

There are also plans for electrification of suburban lines radiating from Leningrad and Khar'kov during 1957. 99/

It has already been mentioned that preliminary work on 1957 projects during 1956 was not so extensive as planned. As of 1 November 1956, none of the 3,700 supports for the catenaries which were supposed to have been supplied to the Chelyabinsk-Kurgan section of the Trans-Siberian line had arrived. The Rayevka-Pokhvistnevo section had received only 78 of 2,700 supports planned and the

Kuybyshev-Syzran' stretch only 78 of 2,488 planned. 100/ Thus the year's work started with a handicap, but not apparently an insuperable one, since the 1957 plan for line electrification was in fact realized.

4. Plans for 1958-60.

About 2,188 km of line were electrified in 1956-57, leaving about 6,046 km of electrified route to be put in operation during 1958-60 in order to fulfill originally announced goals of placing 8,100 km of newly electrified line in operation by 1960.* About 1,694 km are to be put in operation in 1958, and, starting in 1960, no fewer than 2,500 km are to be completed per year. 101/

Therefore, the schedule of electrification for the period 1958-60 appears to be approximately as follows:

Year	Estimated Kilometers of Line to Be Electrified
1958	1,694
1959	1,852
1960	2,500
Total	6,046

Moscow-Ryazan is one of the lines to be completed during 1958. Presumably, electrification of the Zheleznodorozhnaya-Fryazevo-Noginsk and Aleksandrov-Vspol'ye lines will also be completed in 1958. These lines are included in a list of lines in the Moscow area which are being electrified and which are scheduled to be opened for use in 1957 and 1958, 103/ but they do not appear in available lists for 1957 alone. The remaining lines radiating from the Moscow rail center will be electrified for distances of at least 50 to 100 km by 1960. Electrification is also to be completed on the route from Moscow through Khar'kov. 104/

5. Plans for 1961-70.

A general plan for electrification of some 40,000 km of railroad lines during the 15-year period 1956-70 was outlined by the Twentieth Congress of the Communist Party of the USSR and was approved by the Soviet government. The total length of electrified route is

* This calculation assumes that the Irkutsk-Slyudyanka section (134 km) was not included in the 8,100-km plan figure.

supposed to increase from 5,400 km in 1955 to 13,500 km in 1960, to about 29,000 km in 1965, and to about 45,500 km in 1970. 105/ By the 1970's the electrified network is to be 30 percent of the entire rail kilometrage. 106/ The pattern includes routes with high freight traffic density, lines in mountainous areas, lines with heavy passenger traffic, and the suburban lines of large cities. 107/

Electrification of remaining nonelectrified sections of the Trans-Siberian Railroad between Slyudyanka and Vladivostok is to be completed by 1965. 108/ Additional lines connecting Moscow with the Urals will be electrified. Specific stretches named in Soviet publications include the shortest route from Moscow to Sverdlovsk (via Kazan) and a second route to Sverdlovsk Kazan' via Zheleznodorozhnaya, Fryazevo, Petushki, Gor'kiy, Kirov, and Perm', 109/ as well as the route from Moscow to Kirov via Yaroslavl'. 110/ The section branching off the latter line at Danilov and running through Vologda, Konosha, and Kotlas to Vorkuta has also been listed among lines to be electrified after 1960, 111/ and one source also mentions plans for electrification of the route between Leningrad and Vorkuta. 112/

Completion of the electrification of the main lines between Moscow and Leningrad is planned for the 1961-70 period, 113/ and all railroads in the Kuznetsk Basin and in the Urals will be electrified. The dense network of railroads in the Donets Basin and the Krivoy Rog region is to be converted to electric traction. Other important lines to be electrified are the routes from Moscow to Rostov and from Tbilisi to Yerevan (Armenian SSR), 114/ the connection between Slavyansk in the Donets Basin and Rostov, 115/ and the stretch from Armavir to Mineral'nyye Vody. 116/

The remaining lines radiating out from the Moscow rail center are to be electrified for a distance of 50 km to 100 km or more in 1961-70. 117/ In addition, there will be further electrification of suburban lines in other cities, including Leningrad, Kalinin, Riga, Tallinn, Kiev, Khar'kov, Dnepropetrovsk, Rostov, Sochi, Sukhumi, Tbilisi, Baku, Stalingrad, Kuybyshev, Ufa, Gor'kiy, Molotov, Sverdlovsk, Chelyabinsk, Omsk, Novosibirsk, and Irkutsk. 118/

The magnitude of the electrification effort of the USSR for 1961-70 is indicated by the fact that it is planned to electrify 32,000 km of line and to have a total of 45,500 km of electrified line by 1970, whereas at the end of 1950 all other countries of the world combined had only 45,837 km of electrified line. 119/ Thus in a single 10-year period the USSR plans to electrify kilometrage equal to 70 percent of that existing in the remainder of the world in 1950. Although electrification of rail lines in the USSR in the past few years has

been closer to plan than in previous years, it seems unlikely that electrification of 32,000 km of line in 1961-70 will be realized.

B. Plans for Dieselization.

1. 1956-60 Plan.

During the period 1956-60 the total length of lines in the USSR operated by diesel traction is supposed to increase from 6,400 km at the end of 1955 to 26,000 km by the end of 1960. 120/ Lines to be dieselized during this period fall into two principal categories: (a) heavy-density, primarily single-track, lines requiring an increase in capacity but not scheduled for electrification during the Sixth Five Year Plan and (b) lines on which water supply is inadequate and fuel coal is not readily available in adequate quantities. 121/

Priority is being given to dieselization of the following lines: Moscow Belt Railroad, Kalinin-Leningrad, Valuyki-Liski-Rtishchevo-Penza, Chkalov-Kandagach, Dzhusaly-Arys', Karaganda-Mointy, and Akmolinsk-Kulunda-Barnaul. 122/ These and other stretches to be dieselized are shown in Figure 2.*

By 1960, dieselization will be concentrated on lines radiating from Moscow and on lines in dry areas. Lines from Moscow which will be at least partially dieselized (sections in the vicinity of Moscow will be electrified by 1960) include those leading to or toward Leningrad, Kiev, Valuyki, Liski-Rostov-Baku (vicinity), and Kazan'-Sverdlovsk-Nazyvayevskaya. Lines in or into dry areas which are to be dieselized by 1960 include Valuyki-Liski-Saratov-Kandagach-Dzhusaly, Kustanay-Kulunda, Akmolinsk-Kulunda-Barnaul, Karaganda-Chu-Arys', Zharyak-Dzhezkazgan, Aktogay to the Chinese border, Krasnovodsk-Chardzhou-Bukhara, Kungrad-Chardzhou, Kagan-Karshi, Sagiz-Kartaly, Rayevka-Kartaly-Tobol, Gudermes-Astrakhan'-Urbakh. Other lines include Kandalaksha-Petrozavodsk, Kiev-Rostov (with one section electrified), and Leninakan to the vicinity of Baku. 123/

2. Progress in 1956 and 1957.

In 1956, 700 km of line were converted to diesel traction, including Rtishchevo-Penza, Orsk-Kuvandyk, Kagan-Karshi, Urbakh-Anisovka, and Verkhniy Baskunchak - Paromnaya. 124/

The 1957 plan, apparently fulfilled, called for conversion of 1,965 km to diesel traction, including Rtishchevo-Povorino-Valuyki, Dzhusaly-Arys', and Karaganda-Mointy, 125/ as well as all sections of the Moscow Belt Railroad not dieselized earlier. 126/

* Inside back cover.

C. Plans for Production of Locomotives.

According to the original Sixth Five Year Plan, the USSR plans to produce a total of 2,250 main-line, 2-section diesel locomotives (or 4,500 individual units) and at least 2,000 main-line electric locomotives during the 1956-60 period. 127/ The last steam locomotives were produced in 1956. 128/ The planned increase in total horsepower of both diesel and electric locomotives is much greater than the planned increase in inventory of these types of locomotives. The 2,250 2-section diesel units, with a total of 4,000 horsepower (hp) each, will be the equivalent of 9,000 locomotives of the TE-1 type, which are 1,000 hp each.

Annual production figures for diesel and electric main-line locomotives for 1950, 1954-57, and the 1960 plan are shown in Table 8.*

Table 8

Production of Diesel and Electric Main-Line Locomotives in the USSR
1950, 1954-57, and 1960 Plan

Units

Year	Diesel Main-Line Locomotives	Electric Main-Line Locomotives
1950 a/	125	102
1954 a/	120	158
1955 a/	134	194
1956 b/	161	216
1957 c/	400	270
1960 plan d/	1,630 e/	550

a. 129/. Production in 1954 and 1955 consisted primarily of TE-2 diesels, each unit made up of two sections.
b. 130/
c. 131/
d. 132/
e. 133/. The figure for diesel locomotives appears in several sources, accompanied by a statement that production in 1960 will be 12 times greater than that of 1955.

The USSR presumably will also import diesel and electric locomotives from Soviet Bloc countries which are now converting their steam locomotive plants, including Czechoslovakia, Hungary, Poland, Rumania, and East Germany.

D. Related Investment Plans.

During the past 30 years, investment in all transport in the USSR has evidenced a definite percentage decline relative to total investment in the Soviet economy as a whole. While this has been taking place, railroad electrification and dieselization have been receiving an increasing share of the investment allocated to the railroads. Table 9* shows investment in railroads in the USSR, by 5-year periods for 1946-60. This table shows that while total investment in railroads rose from 35.4 billion current rubles in the Fourth Five Year Plan to a planned figure of more than 70 billion rubles in the Sixth Five Year Plan, the percentage for electrification and dieselization combined rose from 3.4 percent in the former period to between 27.2 to 30.0 percent in the latter period. Electrification and dieselization totaling 112,200 km are planned for 1961-70 compared with the planned total of 39,500 km to be achieved by 1960 (see Table 1, p. 6, above). Although many lines with the highest traffic density will have been electrified by 1960 and although the average cost per kilometer may therefore be somewhat less in 1961-70, it is possible that total investment in electrification and dieselization in the 1961-70 period may reach as much as 50 percent of total investment in railroads.

E. Related Traffic Plans.

Soviet plans call for a continued increase in freight traffic during 1956-60. Railroad performance is to increase from 970.9 billion tkm in 1955 to 1,374 billion tkm in 1960 (see Table 2, p. 10, above). No plans have yet been announced for total ton-kilometer performance in 1965 and 1970, but they are estimated at about 1,818 billion tkm and 2,305 billion tkm, respectively.

There is to be a rapid increase in traffic performed by electric and diesel traction from 14 percent of total rail ton-kilometers in 1955 to 43 percent in 1960, 85 percent in 1965, and 100 percent in 1970. In absolute terms this means a planned increase in traffic performed by diesel and electric traction from the 1955 figure of 136 billion tkm to 591 billion tkm in 1960.

Simultaneously, the share of traffic performed by steam traction is supposed to decrease from 86 percent of total freight traffic, or 835 billion tkm, in 1955 to 57 percent, or 783 billion tkm, in 1960 and is to disappear completely by 1970. In 1956, freight traffic performed by steam traction decreased to about 83 percent of the total, but the absolute volume increased to 893 billion tkm. Performance in 1957

* Table 9 follows on p. 32.

Table 9

Total Investment in Electrification and Dieselization of Railroads in the USSR by Five Year Periods 1946-60

Five Year Plan Period	Investment (Million Current Rubles)			Percentage of Total Investment for Railroads		
	Total for Railroads	Electrification a/	Dieselization b/	Electrification	Dieselization	Total Dieselization and Electrification
Fourth (1946-50)						
Plan	40,100 c/	1,300 d/	N.A.	3.2	N.A.	3.2
Actual	35,400 c/	861	371	2.4	1.0	3.4
Fifth (1951-55)						
Actual	45,000 e/	2,755	1,190 f/	6.1	2.6	8.7
Sixth (1956-60)						
Plan	More than 70,000 e/	10,000 to 12,000	9,000 g/	14.3 to 17.1 h/	12.9	27.2 to 30.0

a. Table 4, p. 13, above, gives the methodology for comparable data in 1955 rubles.
b. Table 6, p. 19, above, gives the methodology for comparable data in 1955 rubles.
c. 134/
d. 135/
e. 136/
f. 1955 prices were applied to the entire 5-year period because of a lack of more complete data.
g. Table 6 shows 7,984 million rubles, which is increased to 9,000 million on the basis that the USSR will also import diesel locomotives.
h. Support for this, or a higher, percentage comes from a Soviet statement that about 20 percent of funds allocated for capital construction in railroad transportation in 1957 are for electrification. 137/

showed a further decrease to 80 percent of total traffic but an absolute increase to 967.2 billion tkm. Since production of steam locomotives ceased in 1956, it is obvious why the USSR has not yet begun an accelerated program of scrapping steam locomotives. According to traffic plans, this could not begin before 1960 at the earliest.

Density of traffic on electrified lines is expected to average 21.4 million net tkm per kilometer of line in 1960 (289 billion tkm on 13,500 km of line), and density on lines converted to diesel traction (many of them are single track) is to average 11.6 million tkm per kilometer of track (302 billion tkm on 26,000 km of line), compared with the anticipated network average rail density in 1960 of 10.8 million tkm per kilometer (1,374 billion tkm on 127,200 km of line). 138/ Much higher densities are anticipated on individual electrified and dieselized stretches. For example, density of traffic between Omsk and Novosibirsk on the Trans-Siberian Railroad is the highest in the USSR, primarily because of the heavy flow of Kuznetsk coal to the Urals and the European USSR. Density of westbound traffic alone on this section was 48.7 million tkm per kilometer in 1955, and this same density is to be between 66 and 70 million tkm per kilometer in 1960 and 1965. The leveling off between 1960 and 1965 will be caused by the anticipated diversion of up to 25 million tkm per kilometer to the new Barnaul-Omsk route. 139/

F. Related Operating Plans.

Planned electrification and dieselization in the USSR -- together with other modernization plans such as improved signaling, lengthening of yards and sidings, laying of heavier rails, and acquisition of larger capacity freight cars -- will make possible greater average freight train weight and speed. The net result will be a marked increase in operating efficiency as reflected in gross ton-kilometers per freight train hour. Selected measurements of operating efficiency of Soviet railroads for 1950, 1955-56, and the 1960 plan are shown in Table 10.* Increases in train weight, by type of traction, for 1955-56 and the 1957 and 1960 plans are shown in Table 11.**

Increased train speed will contribute to a decrease in freight car turnaround time. Soviet planners hope to attain a turnaround time of 5.3 days by 1960 140/ compared with 7.5 days in 1950, 6.2 days in

* Table 10 follows on p. 34.
** Table 11 follows on p. 34.

Table 10

Selected Measures of Operating Efficiency of Railroads in the USSR
1950, 1955-56, and 1960 Plan

Year	Average Freight Train Weight (Gross Metric Tons)	Average Freight Train Speed Including Stops a/ (Kilometers per Hour)	Gross Ton-Kilometers b/ per Freight Train Hour
1950	1,430 c/	20.1 d/	28,683
1955	1,758 c/	24.7 d/	43,472
1956	1,831 c/	24.8 d/	45,409
1960 plan	2,200 e/	31.0 f/	68,200

a. Excluding time spent in division terminals.
b. Gross train weight multiplied by train speed.
c. 141/
d. 142/
e. See Table 11.
f. Estimate based on a statement by Kaganovich in May 1954 that speed could be increased a minimum of 6.5 km per hour by 1959 or 1960. 143/

Table 11

Average Gross Train Weight in the USSR, by Type of Traction
1955-56 and 1957 and 1960 Plans

Type of Traction	1955	1956	1957 Plan	1960 Plan
Electric	2,070 a/	2,152 a/	2,265 b/	Almost 2,700 c/
Diesel	1,795 a/	1,939 a/	2,000 b/	N.A.
Steam	1,730 a/	1,789 a/	N.A.	2,000 c/
All types	1,758 a/	1,831 a/	N.A.	2,200 d/

a. 144/
b. 145/
c. 146/
d. 147/

1955, and 6.3 days in 1956.* 149/ The average length of haul of freight was 722 km in 1950, 766 km in 1955, and 787 km in 1956 150/ and is planned to be 750 km in 1960. 151/ This goal will almost certainly not be attained. Although freight car turnaround time is to decrease in 1960 compared with both 1950 and 1955, the average loaded haul of cars is to be longer than in 1950 and only a small percentage less than in 1955.

Because the new electric and diesel locomotives are faster and require less frequent servicing, the distance traversed per day by the electric and diesel locomotives is much greater on the average than that traveled by steam locomotives. Furthermore, the contrast in performance in this respect will become even more marked in the future. Goals announced in 1955 called for an average daily run for electric locomotives in 1960 of 550 km, an increase of 44 percent above 1955, while the average daily run for diesel locomotives in 1960 will be 450 km, an increase of 24 percent above 1955. On the other hand, the goal for steam locomotives in 1960 is 315 km, only 14 percent more than in 1955. The average daily run by type of locomotive for 1955 and 1956 and for the 1957 and 1960 plans is shown in Table 12.**

Performance improved in 1956, when the average daily run of electric locomotives increased 46 km above 1955 and that for diesel locomotives increased 26 km, resulting in a total average daily run of 428 km for electric locomotives and 388 km for diesel locomotives. In 1957 the total average daily run was planned at 465 km for electric locomotives and 415 km for diesel locomotives.

IV. Economics of Changes in Motive Power in the USSR.

A. Comparisons of Different Types of Motive Power.

As a result of constantly increasing economic activity and the accompanying increase in requirements for freight carriage, Soviet railroads have been faced with the problem of increased freight density and of traffic congestion on some overburdened lines. In order to relieve this situation, Soviet railroad planners have decided to increase line capability through dieselization and electrification rather than through installation of third and fourth tracks. Freight density on lines changing over to electric traction between 1956 and 1960 is about three times the average network freight density and on certain sections

* Announcements on performance during the first half of 1957 stated that compared with the first half of 1956 the speed of freight trains had increased and that the plan for speeding up freight car turnaround time had been underfulfilled. 148/

** Table 12 follows on p. 36.

Table 12

Average Daily Run a/ of Locomotives in the USSR
by Type of Traction
1955-56 and 1957 and 1960 Plans

Kilometers

Type of Traction	1955 b/	1956 b/	1957 Plan	1960 Plan
Electric	382	428	465	550 d/
Diesel	362	388	415	450 e/
Steam	277	282	N.A.	315 e/

a. There is some uncertainty as to whether this figure is the actual average daily run per operating locomotive or is an average daily rate which could be attained only if the locomotive operated 24 hours a day.
b. 152/
c. 153/
d. The 1960 plan goal of 550 km is 44 percent above 1955. 154/
e. 155/

even more. 156/ Given a high traffic density on a specific railroad line, Soviet railroad planners must decide whether to electrify or to dieselize and where the investment must first be made to gain the maximum increase in operating efficiency in the shortest possible time. Considerations involved in making these decisions are discussed below.

A Soviet source states that electric traction is effective in the following situations: (1) single-track lines with grades of 1.2 percent and more and a freight flow of more than 5 million tons per year in one direction, (2) double-track lines with grades up to 0.9 percent and more than 25 million to 30 million tons of freight per year in one direction or with grades of 1.2 percent and more and 15 million to 18 million tons per year in one direction, (3) lines with high-density long-haul passenger traffic of over 20 pairs of trains per day, and (4) suburban lines with high-density passenger traffic. 157/

Diesel traction is more effective than electric, according to the same source, in the following situations: (1) double-track lines with grades up to 0.9 percent and a yearly freight flow less than 25 million to 30 million tons in one direction and (2) lines (apparently double track) with grades of 1.2 percent or more and freight flow of up to 15 million to 18 million tons. 158/

1. Relative Operating Efficiency and Effect on Line Capacity.

The steam locomotive in more than 100 years of development has reached a high standard of reliability. Its operation, however, is not economically satisfactory compared with other types of traction either in performance per locomotive or in the relatively high percentage of total rail transport devoted to transport of fuel. Steam locomotives are comparatively heavy per horsepower because of the necessity of carrying along considerable tonnages of coal and water. The tractive force of steam locomotives is low at starting, and the maximum output is reached only at higher speeds. Further significant improvements of steam locomotives cannot be expected without giving up the desired simplicity of design.

In the years since the first use of diesel traction, engines and power transmission systems have been vastly improved. With the introduction of the supercharging principle and light metal construction, the weight of the diesel locomotive is used as an adhesive weight, which permits fuller utilization of the tractive effort for hauling the load. Further progress can be expected in the development of diesel power units both in the engine and in the power transmission system.

In contrast to the mobile power stations embodied in steam and diesel traction units, electric locomotives take their energy from overhead wires which are fed by stationary power generating plants via substations. Electric locomotives, therefore, can be lighter per unit of horsepower. Generally speaking, electric locomotives can start and move heavier loads than steam locomotives. Their motors are able to sustain overloads for short periods, the limit being set by heat generation.

Operational benefits derived from the changeover from steam to diesel or electric traction are considerable. Electric or diesel units are ready for service without the long preparation times needed by steam locomotion for heating up, coaling, taking on feed-water, removing of ashes, cleaning of smoke-box, washing of fire and boiler tubes, and turning the locomotives. The electric locomotive's use of power from overhead wires and the ease of diesel refueling, which takes only a few minutes from pressure-filling stations, result in many more hours of useful employment per day from these types of motive power than would be possible with steam. Both diesel and electric locomotives may be used on longer round-trip runs. Few, if any, locomotive service stops need to be made en route, making it possible to close down many locomotive depots.

Diesel traction deserves preferential consideration over steam in regions lacking either sufficient or suitable water supplies. Compared with the high consumption rate of feed-water for steam locomotives, cooling water requirements of diesel units are insignificant. Even at high performance the diesel cooling system requires almost no attention, because losses from evaporation or leakage are rare. In the USSR, particular attention is being paid to the introduction of diesel hauling in waterless areas such as Turkmen, Tadzhik, Uzbek, and Kazakh SSR's; the Trans-Volga area; and the Caucasus. 159/ Although water requirements of electric locomotives are also insignificant, the lack of a cheap source of electric power in most dry areas and the fact that traffic density is normally low both militate against the use of electric traction in these sections.

The use of diesel locomotives for switching operations is technically and economically profitable (Soviet experience shows that it reduces car layover by 15 percent). The TE-1 diesel locomotives are being used successfully on some lines for this purpose. 160/ On all sections where diesel and electric locomotives are to operate, the plan is to have 300- to 400-hp and 700- to 800-hp diesel locomotives perform switching operations at terminal and intermediate stations. 161/

Dependence of electric locomotives on overhead wires is a limitation on their general availability. By contrast, diesel units can be used on any rail line with suitable rail facilities and, in case of sudden traffic loads, can be concentrated on any line. In the event of military action, the possibility of interference with the overhead wires or the electrical supply system must be considered as a hazard to operations not present with the other forms of traction.

The absence of steam and smoke with either diesel or electric traction improves visibility for locomotive crews and results in greater safety. Another important advantage is the fact that personnel in the enclosed cabs of diesel and electric locomotives are protected against inclement weather and extreme temperatures. In addition, the electric motors on both diesel and electric locomotives are more efficient than steam locomotives in low temperatures such as prevail in much of the USSR in winter. 162/

As mentioned previously,* diesel and electric locomotives permit increases in several measures of operating efficiency. In 1956 the average speed of trains, including stops (except stops at division points and major classification yards) for freight trains, was about 6 percent higher for diesel locomotives and almost 20 percent higher for electric locomotives than it was for steam locomotives. 163/

* See III, F, p. 33, above.

Increased train speed with electric and diesel locomotives results from (a) abandoning the frequent coal and water stops required by steam locomotives, (b) faster acceleration from stops because these locomotives deliver maximum tractive effort at starting, and (c) higher running speeds because these locomotives are not limited by the effects of poor coal or improper use of the controls as is true of steam locomotives.

Either diesel or electric locomotives can offer considerably higher horsepower outputs than can the steam locomotive without requiring additional personnel because two or more power units may be combined and operated by one locomotive crew in the front unit.

Diesel and electric traction make possible the hauling of heavier train loads at higher speeds, and the result is increased line capacity. The degree of advantage derived, in terms of line capacity, however, depends in part on the length of tracks in stations and on sidings, condition of main-line track and roadbed, signaling facilities, and the proficiency and availability of competent maintenance and operating personnel. The advantages of speed and freight-carrying ability might also be limited by the use of obsolete freight cars. According to a Soviet source, the over-all effect of installing electric traction is to increase a railroad's capacity by 150 to 250 percent above its capacity with steam operation. 164/ On a single-track line the capacity increases 1.5 times. 165/ A more recent source states that train capacity of a rail line increases 80 percent with diesels and 100 percent with electrics compared with steam locomotive operation. 166/ Soviet experience further shows that, by the use of electric traction on even terrain, line capacity may be increased by 1.7 to 2.0 times and on mountainous terrain by 2.5 to 3.0 times. 167/

The relative economy of electrification of railroads to achieve increased capacity is shown in the following tabulation 168/:

Type of Construction	Cost (Thousand Rubles per Kilometer)*	Percentage Increase in Capacity
Electrification**	200	Almost 100
New alternate line***	600 to 800	100
Double tracking****	500 to 600	200 and more
Powerful locomotives†	120 to 150	40 to 50

* Prewar prices.

** Apparently of a single-track line. The figure probably excludes cost of electric locomotives.

*** Apparently single track.

**** This appears to be the cost of installing a second track on an existing single-track line, apparently to be operated with steam locomotives.

† Apparently the cost of improved facilities only.

Although costs of the various types of construction given in this tabulation have changed, it is likely that the relationship between them is still valid. Compared with the cost of electrifying a single-track line, it would cost 3 to 4 times as much to obtain a similar capacity increase through construction of a new alternate single-track line. Although double-tracking increases capacity at least 3 times more than does electrification of a single-track line, the cost of double tracking is 2.5 to 3 times the cost of electrification. Double tracking, therefore, would be done only if traffic density were too great for a single-track electrified line to handle.

Similar savings would be achieved by electrifying a double-track line with high traffic density rather than by continuing steam operation and installing a third and possibly fourth main-line track.

2. Relative Costs of Electrification and Dieselization.

It is apparent that the USSR, in establishing its capital investment priorities in the field of transportation, has pursued objectives not dissimilar to those motivating investment in free economies. The USSR has striven to allocate its investment in order to obtain the greatest possible increases in productivity (ton-kilometers of freight). Moreover, in selecting the electrification and dieselization programs, the USSR has also channeled this investment into programs which attain this objective through considerably reduced operating costs over shorter periods of time and which yield the greatest return per ruble of new investment.

a. Initial Investment.

It is estimated that between 1956 and 1960 the average investment for electrification of primarily double-track line, including related improvements to signaling, communications, and housing and the cost of electric locomotives, will be between 1,233,000 and 1,480,000 rubles per kilometer (see Table 4, p. 13, above). By contrast, the estimated average investment for dieselization of primarily single-track line, including related improvements and the cost of diesel locomotives, will be about 407,000 rubles per kilometer (see Table 6, p. 19, above). It is estimated that the cost of dieselization of a double-track line, including locomotives, would be somewhat less than double this amount, perhaps in the magnitude of 700,000 rubles. Thus the total initial cost of dieselizing a double-track line is about one-half that of electrification. One of the major factors in determining whether to dieselize or electrify a line, therefore, would be the relative costs of electric power and diesel fuel.

There are only scattered data available on the cost of installing steam locomotive facilities on new rail line and on the cost of steam locomotives. It is estimated, however, that the cost of steam locomotive facilities (repair sheds or roundhouses, coal and water towers, and turning Y's or turntables) would be relatively high compared with the cost of diesel facilities because many more facilities are necessary with steam operation.* The cost per steam locomotive unit is considerably less than that per diesel unit -- about 300,000 rubles for a steam locomotive and about 1.1 million rubles for a TE-1 diesel locomotive. 171/ However, because each diesel locomotive does the work of 2 or 3 steam locomotives, fewer diesel locomotives are required. On balance, therefore, it is estimated that the initial cost per kilometer of steam locomotive facilities plus steam locomotives would be somewhat greater than the cost of diesel facilities and locomotives, although it would be significantly less than the initial cost of electrification and electric locomotives.

b. Operations.

The USSR is counting on lower operating costs to offset the initial capital investment necessary for conversion to diesel and electric traction. Soviet sources have claimed that capital expenditure for introduction of diesel traction sufficient to carry 40 percent of the freight turnover on the railroads would pay for itself in less than 3 years, apparently in operating savings over steam traction. It is estimated by the USSR that the cost of hauling under diesel traction as opposed to steam traction is reduced by between 30 and 35 percent. 172/ Decreased operating costs resulting from electric traction will permit the USSR to recover the initial capital outlay in from 3 to 10 years. Differences in traffic levels would account for

* An indication of these costs is given in a Soviet article discussing the conversion of steam locomotive terminals to diesel and electric locomotive terminals. The average cost of converting steam repair and servicing facilities so that diesels can be handled ranges from 28,000 to 50,000 rubles per kilometer; to convert them for handling electric locomotives, from 20,000 to 40,000 rubles per kilometer; and to convert them to handle steam locomotives with capabilities comparable to the TE-3 diesel or N-8 electric, from 130,000 to 165,000 rubles per kilometer. 169/ Another indication of these costs is given by the statement that to handle 40 percent of total freight movement (for an unspecified year), capital expenditure, including expenses to affected branches of industry, would be as follows: dieselization, 16 billion rubles; electrification, 70 billion rubles, and introduction of heavy steam locomotives, 28 billion rubles. 170/

the wide range of years given. Funds spent for dieselization, including diesel locomotives, have been recovered in from 1 1/2 to 2 years through savings in operating expenses. 173/

Total operating costs depend on many separate outlays, most of which vary depending on the amount of traffic carried. Costs which change almost proportionately with the amount of traffic include the following: cost of fuel; wages of personnel; cost of operation of engine sheds and workshops (including personnel, materials and spare parts); and interest and amortization for locomotives. Costs which are relatively fixed and which do not change proportionately with the amount of traffic include administrative costs and interest and depreciation on capital investment for fixed installations, including water and fuel facilities, engine sheds, and workshops. The cost of electric substations may vary with traffic because the number installed must increase with large increases in traffic.

The hypothetical schematic relationship of these costs to volume of traffic is shown in Figure 4.* 174/ At the intersection of the total cost lines A3, B3, and C3, two forms of traction become equivalent in operating cost for a certain amount of traffic. Considering operating costs only, steam traction is cheapest below a certain traffic volume (P). Between this volume (P) and a somewhat higher traffic volume (R), diesel traction is cheapest, and above this volume (R) electrification is cheapest. The specific volume of traffic for which one form of traction becomes cheaper than another depends on many factors, including the cost of fuel and electricity as well as the system of electrification used. These factors vary from one railroad division to another.

Operating costs for 1954-55 by type of traction on the Omsk railroad system, which has the highest freight traffic density in the USSR, are shown in Table 13.** This system probably has relatively low operating costs. On the basis of total costs, if operating costs with electric locomotives equal an index of 100, then diesel costs equal 132 and steam costs equal 165.

Another Soviet statement of comparative operating costs of steam*** and diesel locomotives for 1952-56 is shown in Table 14.****

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* Following p. 42.

** Table 13 follows on p. 43.

*** There are no Soviet figures available on costs of operating oil-burning steam locomotives. Within the past few months, there have been a number of indications that some coal-burning steam locomotives have been converted to oil. It is believed, however, that only a small number of steam locomotives have been so converted.

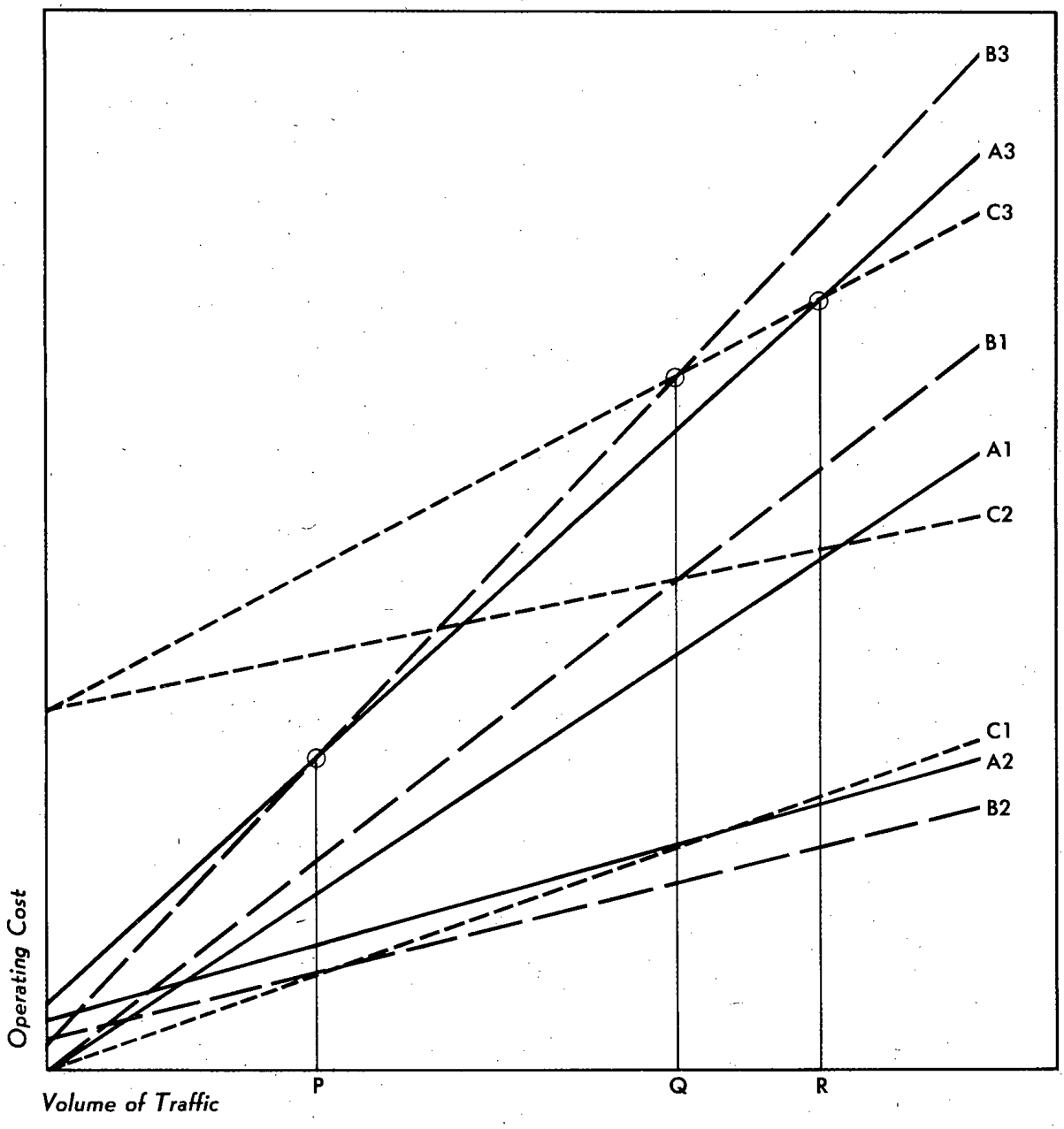
**** Table 14 follows on p. 44.

Figure 4

50X1

US AND USSR

RAILROAD OPERATING COSTS IN RELATION TO VOLUME OF TRAFFIC



A = Steam Traction
B = Diesel Traction
C = Electrification

INDEX 1 = Proportional Costs
INDEX 2 = Non-proportional Costs
INDEX 3 = Total Costs

26116 2-58

50X1

Table 13

Operating Costs on the Omsk Railroad System a/
by Type of Traction
1954-55

Rubles per 10,000 Gross Ton-Kilometers

Type	Total b/	Salary of Freight Locomotive Crews	Salary of Freight Train Crews	Locomotive Fuel or Power	Lubrication and Lighting of Locomotives
Steam	30.02	6.84	3.23	19.43	0.52
Diesel c/	24.08	7.63	2.69	13.39	0.37
Electric	18.22	3.08	2.30	12.80	0.04

a. 175/. Data for diesels are for 1954-55. It is inferred that remaining data are for the same period.
b. Totals do not include all elements of operating cost. According to the Sixth Five Year Plan, the share of amortization in total operating costs will rise from 17.1 percent in 1955 to 21.5 percent in 1960, and outlays for medium annual and current repairs of fixed capital will rise from 12 percent to 15 percent of the total cost. 176/
c. Data for Petropavlovsk division only.

Table 14 is not completely comparable with Table 13, because it includes locomotive repair and an undefined item, "renovation" costs, but apparently excludes the cost of train crew and lubricants. This table also shows that total operating costs per 10,000 gross tkm with steam locomotives are 2.5 times the costs with diesel operation.

Fuel costs make up a large percentage of total operating costs, as shown in Tables 13 and 14. Fuel consumption of diesel locomotives and power consumption of electric locomotives are largely independent of the skill of operating personnel because operation of these locomotives is relatively automatic. Some saving of power may be achieved on electric locomotives through regenerative braking, which permits power produced by the electric motors during braking to be fed into the power lines. 180/ Economy of fuel consumption with steam locomotives depends to some extent on the "art" of firing, so that savings of fuel can be achieved by skilled firemen and engineers.

Table 14

Comparative Operating Costs of Steam and Diesel Locomotives in the USSR a/
1952-56

Rubles per 10,000 Gross Ton-Kilometers

Costs	Steam Locomotives	Diesel Locomotives
Fuel b/	43.7	9.7
Repair c/	11.1	7.2
Locomotive crew d/	9.45	5.95
Renovation e/	0.85	3.14
Total	65.10	25.99

a. 177/
b. Source states that the cost of standard* diesel fuel is 263 rubles per ton and that the cost of hard coal (source does not specify whether it is based on standard units) is 148 rubles per ton. Dividing the costs in Table 13, p. 43, above, by these prices yields consumption per 10,000 gross tkm of 36.9 kilograms (kg) of standard diesel fuel and 296 kg of unspecified coal fuel. The figure for diesel fuel is somewhat lower than an average (possibly 1955) of 44.3 kg for "modern diesel" given in another source, 178/ and the average coal consumption in terms of standard fuel ranged from 211 kg per 10,000 gross tkm in 1952 to 194 kg in 1955. For electric locomotives a consumption per 10,000 gross tkm of 179 kwh (80.3 kg in standard fuel equivalent) is reported for 1954. 179/
c. Source states that expenditures on terminal repairs for these locomotives are average figures for the whole rail net.
d. Train crew is considered to include three men, according to source. This includes, therefore, only the locomotive crew.
e. Source gives no indication of the meaning of this term, which is not normally used in Soviet literature.

3. Net Savings from Dieselization and Electrification.

Savings realized from diesel and electric operation, as opposed to continued operation with steam traction, will quickly offset

* Standard fuel is the common statistical denominator for energy output of various fuels; it is a theoretical 7,000-caloried fuel.

the initial investment in these modernized forms of traction. In each ensuing year the total net saving will continue to increase. Savings that should be effected by the introduction of diesel and electric traction in the USSR in 1956-60 are shown in Table 15.*

A saving of 11.79 billion rubles is estimated to be accrued during 1956-60 from the partial changeover to diesel and electric traction. These savings will partially offset the planned investment of 10 billion to 12 billion rubles in electrification and electric locomotives and about 9 billion rubles in dieselization during this period.

According to a Soviet statement, operating expenses, apparently from electrification alone, are expected to be reduced by more than 1 billion rubles in 1960, apparently compared with 1955. 181/ According to another Soviet source, in 1956 electric traction will reduce operating expenses by more than 3 billion rubles. This source estimates that expenditures for rail electrification during 1956-60 will be recovered in about 7 years and that investment in electrification after 1960 will be recovered in about 5 years. 182/ As indicated above,** investment in dieselization may be covered in from 1-1/2 to 2 years.

The savings estimated above are a reflection of total savings in operating costs, including administration, labor, fuel, materials, spare parts, and interest and depreciation on capital investment. The USSR estimates that the amount of coal that will be saved by the electrification of railroads in 1956-60 will reach 25 million tons a year by 1960 and that further electrification is expected to bring the annual savings to 87 million tons by 1970. (Table 18*** presents detailed data on savings of coal.)

The Moscow-Kuybyshev-Vladivostok line is an example of potential savings from electrification of rail lines. The USSR expects the conversion of this stretch of 9,447 km to electric traction to save about 3 billion rubles annually in operating expenses, and planned total capital investment for the electrification of the line is set at nearly 9 billion rubles. Factors which will effect this operating saving include reduction of the number of locomotives by nearly 50 percent, the closing of some depots, and the reduction of the number of servicing personnel by more than 12,000. 183/****

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* Table 15 follows on p. 46.
** See IV, A, 2, b, p. 41, above.
*** See p. 63, below.
**** Continued on p. 50.

Table 15

Estimated Savings from Increased Diesel and Electric Traction in the USSR
1956-60

Year	Type of Traction	Net TKM Performed or Planned (Billions)	Average Cost per TKM a/ (Kopeks)	Total Cost of Transport (Billion Rubles)	Savings (Billion Rubles)
1956	Assuming 1955 Traction Mix	1,079 b/	4.2	45.32	
	Estimated: Steam	894 b/	4.39	39.25	
	Electric	111 b/	3.07	3.41	
	Diesel	74 b/	3.29	2.43	
	Total	1,079 b/	4.18	45.09	0.23
1957	Assuming 1955 Traction Mix	1,209 b/	4.2	50.78	
	Estimated: Steam	967 b/	4.39	42.45	
	Electric	145 b/	3.07	4.45	
	Diesel	97 b/	3.29	3.19	
	Total	1,209 b/	4.14	50.09	0.69

Table 15

Estimated Savings from Increased Diesel and Electric Traction in the USSR
1956-60
(Continued)

Year	Type of Traction		Net TKM Performed or Planned (Billions)	Average Cost per TKM a/ (Kopeks)	Total Cost of Transport (Billion Rubles)	Savings (Billion Rubles)
1958	Assuming	1955 Traction Mix	1,328 c/	4.2	55.78	
	Estimated:	Steam	N.A.	4.39	N.A.	
		Electric	N.A.	3.07	N.A.	
		Diesel	N.A.	3.29	N.A.	
		Total	1,328 c/	4.04	53.65	2.13
1959	Assuming	1955 Traction Mix	1,456 c/	4.2	61.15	
	Estimated:	Steam	N.A.	4.39	N.A.	
		Electric	N.A.	3.07	N.A.	
		Diesel	N.A.	3.29	N.A.	
		Total	1,456 c/	3.96 d/	57.66	3.49

Table 15

Estimated Savings from Increased Diesel and Electric Traction in the USSR
1956-60
(Continued)

Year	Type of Traction	Net TKM Performed or Planned (Billions)	Average Cost per TKM a/ (Kopeks)	Total Cost of Transport (Billion Rubles)	Savings (Billion Rubles)
1960	Assuming 1955 Traction Mix	1,595 c/	4.2	66.99	
	Estimated: Steam	909 b/	4.39	39.91	
	Electric	335 b/	3.07	10.28	
	Diesel	351 b/	3.29	11.55	
	Total	1,595 c/	3.87	61.74	5.25
Total					11.79

Table 15

Estimated Savings from Increased Diesel and Electric Traction in the USSR
1956-60
(Continued)

a. The average cost per railroad net ton-kilometer in 1955 was 4.2 kopeks. 184/ The Minister of Railroads reported that electric traction reduced the cost of shipment 28 to 30 percent and that diesel traction reduced the cost 25 percent. 185/ Estimates in this column are based on these statements, taking into account the proportion of ton-kilometers handled by each type of traction in 1955. The average cost for each type will probably decrease because of retirement of obsolete steam locomotives and gradually increased efficiency of diesels and electrics. However, the net savings should not be significantly affected, and the 1955 cost is therefore used for the entire calculation in this table.
b. See Table 2, p. 10, above, for percentage distribution.
c. 186/. The estimated average length of haul is increasing despite the plan to decrease. Therefore, actual ton-kilometers should be in excess of the plan.
d. Estimated by interpolation between 1957 and 1960 values.

Tangible savings in important resources such as fuel and labor appear to be the major factor influencing the Soviet decision to initiate and to carry out the large-scale changeover in the type of motive power for railroads now taking place.

B. Comparison with the US.

1. Relative Rate of Change to Electric and Diesel Power.

Soviet long-range planning calls for substantial annual increases in the volume of traffic handled by diesel and electric traction and for the complete elimination of steam traction by 1970. A comparison of estimated percentage distribution of ton-kilometers of railroad freight for the USSR and the US, by type of traction, for selected years, 1940-70, is shown in Table 16.* These data are also shown graphically in Figure 5.** The rate of change from steam to diesel or electric traction in the USSR is significantly slower than it was in the US despite the significantly higher freight traffic density on Soviet railroads. In 1955, average freight traffic density in the USSR was 8 million tkm per kilometer of line (based on figures in Tables 1 and 2, pp. 6 and 10, respectively, above), and in the US it was only 2.6 million tons per kilometer. 187/ Therefore, freight traffic density in the USSR was 3.1 times that in the US. In 1945, total electric and diesel ton-kilometers were 4.2 percent of total Soviet traffic and 8.9 percent of total US traffic. In 1955 the percentage in the USSR had risen to only 14 percent, whereas in the US the figure had reached 87.5 percent. It is anticipated that by 1960 all except a fraction of 1 percent of US freight traffic will be hauled by diesels and electrics, of which almost all will move by diesel. In that same year the USSR intends to handle only 43 percent of its freight traffic by electrics and diesels and 57 percent by steam.

In 1945 the railroads of the US were dependent on steam traction for more than 90 percent of their ton-kilometer performance. A dynamic shift from steam to diesel traction took place, however, and in 1954 the US was handling by diesel 84 percent of its freight traffic, 86 percent of its passenger traffic, and 90 percent of its yard switching. 188/ The use of electric motive power has been relatively minor, and its relative importance changed very little during this period. Yet performance on the Pennsylvania Railroad's high-density electrified New York - Washington line could probably not be equalled by any other form of motive power, and any significant encroachment by diesels, except for switching service, seems improbable. In addition, durability of an electrified system has also been established. For

* Table 16 follows on p. 51.
** Following p. 50.

Figure 5

US AND USSR

ESTIMATED PERCENT OF TON-KILOMETERS PERFORMED BY RAILROADS BY TYPE OF TRACTION, SELECTED YEARS, 1945-60

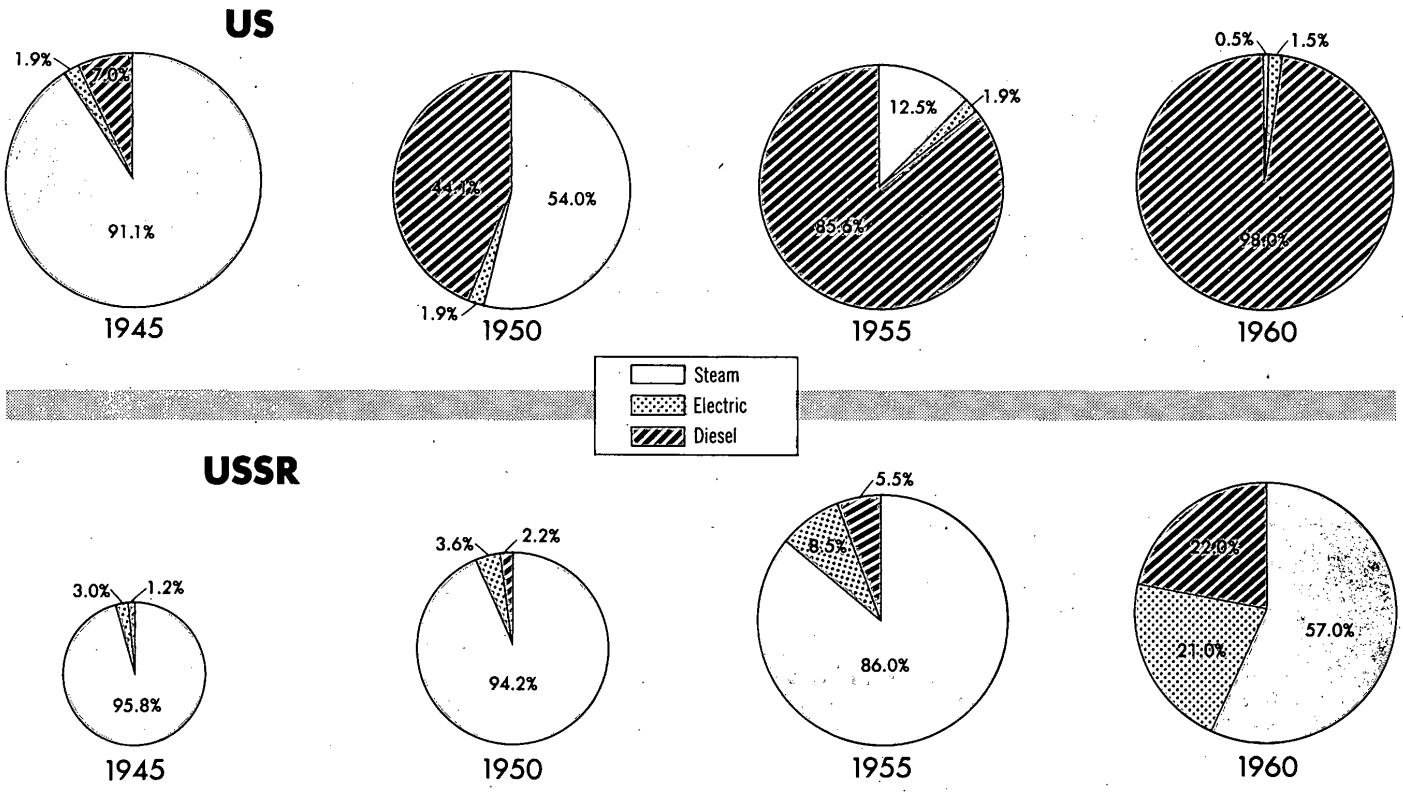

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Table 16

Comparison of Estimated Percentage Distribution of Ton-Kilometers of Railroad Freight in the USSR and the US by Type of Traction Selected Years, 1940-70

Percentage

	USSR a/				US b/			
Year	Steam	Electric	Diesel	Total Electric and Diesel	Steam	Electric	Diesel c/	Total Electric and Diesel
1940	97.4	2.4	0.2	2.6	N.A.	N.A.	N.A.	N.A.
1945	95.8	3.0 d/	1.2 d/	4.2	91.1 e/	1.9 e/	7.0 e/	8.9
1950	94.2	3.6	2.2	5.8	54.0 e/	1.9 e/	44.1 e/	46.0
1955	86.0	8.5	5.5	14.0	12.5 e/	1.9 e/	85.6 e/	87.5
1960	57.0	21.0	22.0	43.0	0.5 f/	1.5 f/	98.0 f/	99.5
1965	15.0	43.0	42.0	85.0	0.1 f/	1.4 f/	98.5 f/	99.9
1970	0.0	55.0	45.0	100.0	0.0 f/	1.0 f/	99.0 f/	100.0

a. Data are from 189/ except as otherwise indicated.
b. US statistics are for Class I railroad freight operation, which include all except 0.5 percent of the rail ton-kilometers in the US.
c. Including a fractional percentage of gas-turbine locomotive operation.
d. Interpolation; exact statistics are not available.
e. 190/
f. Estimated on the basis that steam traction will be virtually nonexistent in the US by 1960 and on the current trend to abandon some electrified operation in favor of diesels.

example, the Milwaukee and the New York, New Haven & Hartford Railroads are using electrified systems which are more than 40 years old. 191/ The Virginian Railway's electrified sector, in existence since 1925, has proved itself to be similarly durable.

The diesel locomotive is dominant in the US, however, despite the enviable record of electric locomotives discussed above and despite the notably low maintenance costs for electric locomotives (about half that for diesels). In the US, obsolescence and maintenance costs indicate that diesels have an economic life which is closer to 12 years than to the 20 years originally planned. Despite these facts, there seems little prospect for expansion of the electrified mileage in the US, and a high percentage of US rail mileage is now completely dieselized.

The major reason for this dieselization is that in the US the disadvantages of electrification outweigh those of dieselization. There are several disadvantages to electrification of railroads in the US, including the high capital investment required. Because of the uncertainty of providing a reasonable return to investors, it would be difficult to finance a major US railroad electrification project. It is estimated that a net return of about 12.5 percent would be required in order to make such an investment attractive to US investors even on a short-term basis. Because capital costs of dieselization can be amortized in a relatively few years, whereas electrification costs require a long amortization period, no electrification is at present being planned by any US railroad. A second disadvantage is that electrification is desirable only when train density is very high. US railroads have low density in terms of numbers of trains moving on any one line compared with densities of European and Soviet railroads. A third disadvantage is that there are long-term increases in maintenance costs and taxes on electrified facilities. By contrast, dieselized lines have fewer fuel and repair facilities than steam locomotives, reducing both maintenance costs and taxes compared with those under steam operation. Management hesitates to make such long-term increases in expenditures when long-term traffic and income prospects are uncertain. This uncertainty arises from changes in the relative effectiveness of competition from highway and water carriers, which depend in part on changes in federal and state rate and regulatory policies, and from the rise in labor and material costs.

With present developments in research, there is no assurance that some new form of motive power may not come into the picture in the US in the next few years which will rapidly replace diesels. Similar developments in the USSR could cause a change in plans for dieselization and electrification. Not even the most optimistic proponents of the

diesel locomotive would have dared to predict 15 years ago that the change from steam would take place so rapidly in the US. Although the ultimate elimination of steam traction is a virtual certainty in both the US and the USSR, the types of traction to which both may shift will depend on prototypes now in various stages of development in both countries.

Further developments in railroad electrification, including atomic power stations, might significantly lower capital investment and operating costs. Combined with rising prices of diesel fuel, this could result in a major changeover to electrification in the US as well as the USSR and a cutting back of the Soviet diesel program and expansion of electrification beyond present plans. The high present initial capital investment necessary for electrification, however, as well as other factors discussed below, will probably continue to retard investment in the US in this field. The USSR will probably continue to electrify, though probably not so rapidly as planned, because it has no major investment problems and possesses economically advantageous sources of electric power. Both the US and the USSR can, of course, be expected to take advantage of new developments in other fields of research such as atomic and/or gas-turbine locomotives.

2. Relative Operating Efficiency.

US railroads have consistently outperformed the railroads of the USSR in terms of total freight locomotive performance as expressed in net ton-kilometers per locomotive. However, with both diesel and electric locomotives, the USSR is now obtaining better performance than US railroads. A comparison of freight locomotive performance in the US and the USSR, by type of traction, for selected years, 1940-55, is shown in Table 17.* The US superiority was caused by better steam locomotive performance and in postwar years by the higher proportion of traffic performed by diesel locomotives. It was probably also aided by the smaller number of locomotives in reserve and perhaps also by the lower traffic density on US lines.

The US is now approaching almost complete dieselization, however, and can expect a leveling off of total locomotive performance, whereas the USSR, just recently embarked on an extensive dieselization and electrification program, may expect great strides in the improvement of this critical index of operating efficiency.

In 1955, both the US and the USSR experienced the highest performance per unit from electric freight locomotives, although diesel freight locomotives were a close second. Both forms of modern traction far outperformed the old, obsolete steam locomotive.**

* Table 17 follows on p. 54.

** Continued on p. 56.

Table 17

Comparison of Freight Locomotive Performance in the US a/ and the USSR, by Type of Traction Selected Years, 1940-55

Year	Estimated Net Ton-Kilometers (Billions)		Estimated Inventory (Units)		Estimated Net Ton-Kilometers per Locomotive (Millions)	
	US	USSR	US	USSR	US	USSR
All Freight Locomotives						
1940	544.9 b/	415.0 c/	26,111	20,833	20.9	19.9
1945	944.3 b/	314.0 d/	27,039	20,616	34.9	15.2
1950	859.3 b/	602.0 c/	24,267	25,272	35.4	23.8
1955	910.5 b/	970.9 c/	17,868	30,803	51.0	31.5
Steam Freight Locomotives						
1940	N.A.	404.2 c/	25,677 e/	20,560 f/	N.A.	19.7
1945	905.8 g/	300.8 h/	25,577 e/	20,240 f/	35.4	14.9
1950	464.0 g/	567.4 c/	17,291 i/	24,440 f/	26.8	23.2
1955	114.8 g/	835.0 c/	3,838 j/	29,800 f/	29.6	28.0
Electric Freight Locomotives						
1940	N.A.	10.0 c/	422 e/	224 k/	N.A.	44.6
1945	18.9 g/	9.4 h/	438 e/	231 k/	43.1	40.7
1950	16.3 g/	21.7 c/	399 i/	440 l/	40.8	49.3
1955	17.3 g/	82.5 c/	304 j/	1,147 m/	56.9	71.9 n/
Diesel Freight Locomotives						
1940	N.A.	0.8 c/	12 e/	49 o/	N.A.	16.3
1945	69.6 g/	3.8 h/	1,044 e/	145 o/	66.6	26.2
1950	379.0 g/	13.2 c/	6,577 i/	392 p/	57.6	33.6
1955	779.4 g/	53.4 c/	13,726 j/	889 q/	56.8	60.0 n/

a. All US statistics are for Class I railroads only.
b. 192/
c. Information from Table 2, p. 10, above.
d. 193/

Table 17

Comparison of Freight Locomotive Performance
in the US a/ and the USSR, by Type of Traction
Selected Years, 1940-55
(Continued)

e. 194/. Freight locomotive figures adjusted to include 78 percent of "freight or passenger locomotives."
f. 195/. Eighty percent of total steam locomotives are estimated to be main-line freight types.
g. 196/. Calculated from percentage distribution.
h. Based on percentage distribution estimated in Table 16, p. 51, above.
i. 197/. Estimates reflect adjustment to include representative percentage of "freight or passenger locomotives."
j. Estimates reflect adjustment to include representative percentage of "freight or passenger locomotives."
k. Based on total production plus imports as shown in Table 3, p. 11, above, with no retirements.
l. Based on Table 3, p. 11, above, minus estimated retirement of 30 units.
m. Based on Table 3, p. 11, above, minus estimated retirement of 45 units.
n. Productivity per electric locomotive is stated in a recent Soviet periodical 198/ to have risen from a daily average of 640,000 gross tkm in 1955 to 705,000 gross tkm in 1956, and the corresponding productivity figures for diesel locomotives were 531,000 and 608,000 gross tkm, respectively. Multiplying by 365 days, a 1955 yearly productivity of about 262 million gross tkm for electric and 194 million gross tkm for diesels is derived. However, productivity of 262 million gross tkm per electric locomotive compared with 71.9 million net tkm in this table is inconsistent. These two figures give a net to gross ratio of 27 percent; the diesel ratio is 31 percent. This ratio should be approximately 55 percent, indicating that the above daily train run figure (see Table 12, p. 36, above) is probably a rate rather than an actual performance figure.
o. Based on total production plus imports, as shown in Table 5, p. 16, above, with no retirements.
p. Based on Table 5, p. 16, above, minus estimated retirement of 10 units and minus 96 imported from the US (see explanation in II, B, 3, p. 15, above).
q. Based on Table 5, p. 16, above, minus estimated retirement of 25 units and minus 96 imported from the US.

3. Relative Costs of Electrification and Dieselization.

a. Line Structures.

Although no electrification of US railroads has taken place since World War II, plans have been drawn and estimates made on a few stretches of line. These estimates show US costs (1955) of approximately $135,000 per kilometer for building the structures and substations necessary for the electrification of a double-track line, including signal and communication changes. Steel towers or bridges 285 feet apart were planned to support the catenary system. No substantial changes to the right of way were contemplated. A recent estimate for electrifying a 4-track main-line section in the US came to $188,000 per kilometer. This estimate provided for the use of treated wooden poles wherever possible and obviously did not include any track changes or extras.

In the USSR during 1956-60, expenditures for the electrification of a double-track line are planned to be between 747,000 and 1,044,000 rubles per kilometer (see Table 4, p. 13, above). This cost includes the installation of high-tension transmission line, enlarging power stations, equipping the line with improved signal and communication facilities (particularly automatic block signals and centralized dispatching), and new housing, but it excludes the cost of electric locomotives.

A better comparison of the costs in the two countries could be obtained if the same items were included in the estimates for both countries. The type of construction also is not entirely comparable. On the section of track from Omsk to Nazyvayevskaya the steel truss towers apparently were spaced 41 meters (135 feet) apart, which is just under half the distance of a recent US proposal. 199/ The US catenary system is presumably of heavier construction and includes at least one messenger wire in addition to the contact wire itself. There has been an effort made in the USSR to bring down the cost of the trusses by substituting reinforced concrete for steel. 200/ It is stated that such substitutions should reduce the cost of construction by almost half. 201/ Thus far this reduction has not been realized. It would seem, however, that the initial costs of line electrification in the US and in the USSR are similar when comparable items are included.

Adequate data are not available for costs of line changes and improvements incident to dieselization in the US. The USSR, however, announced that it plans to spend between 30,000 and 48,000 rubles per kilometer for this purpose.

b. Locomotives.

Few electric locomotives have been purchased in recent years in the US, and prices have changed considerably since World War II. The highest price paid by the Pennsylvania Railroad for a GG-1 (4,620 hp) was $272,800, which was in the period between 1937 and 1943. Today it is estimated that an individual GG-1 replacement would cost $650,000. Studies of new designs of rectifier locomotives for eventual replacement of the P-5a electric locomotive seem to favor a 5,400-hp 6-axle locomotive which, it is estimated, may be procured in lots of 100 for $445,000 per unit.

No prices are available for newer types of Soviet electric locomotives. The older VL-22m is believed to cost about 1,772,000 rubles per unit. At 3,270 hp (see Table 4, p. 13, above) this locomotive cost 542 rubles per horsepower compared with 59 dollars per horsepower for the US GG-1. This yields an approximate 1947 ruble-dollar ratio of 9.2 to 1. The 5,400-hp locomotives proposed for the Pennsylvania Railroad will cost about $82 per horsepower.

A value given for a set of ten 1,500-hp diesels to be purchased shortly by the Great Northern Railway is $180,000 each. 202/ For other railroads buying in large quantities, diesel locomotives have been priced from $175,000 to $186,000. 203/

The US 1,500-hp locomotive costing $180,000 is worth $120 per horsepower compared with 800 rubles for the TE-3, or an approximate ruble-dollar ratio of 6.7 to 1. However, if the US 1,500-hp locomotive costing $186,000 in 1955 is compared with the Soviet TE-2 at 2,120,000 rubles, a 1955 ruble-dollar ratio of 8.6 to 1 is established.

c. Fuel and Power.

The average cost of all electric power used in traction in the US in 1955 was 1.122 cents per kilowatt-hour. 204/ In addition, 185.4 kwh were required per 10,000 gross tkm of road freight service. This means that 10,000 gross tkm were moved for $2.08.

Rates paid by the Soviet railroads for electricity for electrified transport effective in 1955 range from a low of 4.9 kopeks per kilowatt-hour in Armenia to a high of 18 kopeks per kilowatt-hour in Bashkiria. 205/ On this basis, it is estimated that the average rate per kilowatt-hour of electricity purchased by the Soviet railroads in 1955 was about 12 kopeks (0.12 rubles) per kilowatt-hour. Consumption of electricity per 10,000 gross tkm in the USSR in 1955 was 161 kwh, 206/ or slightly below the US figure. Because the cost of power for electric

operation in the USSR is 19.3 rubles per 10,000 gross tkm compared with the US figure of $2.08, a 1955 ruble-dollar ratio of approximately 9.3 to 1 is indicated.

In the US the cost of diesel fuel has risen from 5.5 to 9.6 cents per gallon from 1946 to 1954. 207/ The railroads are experimenting with the use of lower grade fuel oils on diesels, sometimes at the risk of increased maintenance. 208/ In 1955 the average cost to the railroads of diesel fuel was 9.81 cents per gallon (including freight and handling expenses). 209/ At 3.2 kg per gallon this would be the equivalent of approximately $30 per ton (3 cents per kg). An estimated Soviet price of diesel oil in the Black Sea area was 300 rubles per ton, indicating a ruble-dollar ratio of 10 to 1.

In 1955, diesel freight locomotives in the US consumed an average of 16.8 gallons per 10,000 gross ton miles, 210/ or about 33.3 kg per 10,000 gross tkm. At 3 cents per kilogram this costs $1 per 10,000 gross tkm. Average Soviet consumption of diesel oil in freight service was announced in 1947 as 45 kg of standard fuel per 10,000 gross tkm. 211/ On at least one railroad system in 1955, however, consumption averaged 50 kg of standard fuel per 10,000 gross tkm. 212/ A standard fuel figure of 50 kg, when reduced by 28 percent to convert to actual fuel, amounts to 36 kg of actual fuel, which is similar to the US figure. At 0.30 rubles per kg the Soviet cost is 10.8 rubles per 10,000 gross tkm. Thus electric power costs per 10,000 gross tkm in the USSR were estimated at 19.3 rubles in 1955 compared with diesel fuel costs of only 10.8 rubles. On this basis, electric power costs in 1955 were 1.8 times higher per unit of traffic than were diesel fuel costs.

d. Operations.

US data are inadequate to permit a calculation of comparative costs of US and Soviet operation with diesel and electric locomotives. Rough calculations using gross operating revenues indicate a ratio of 4.6 rubles to $1 per unit of freight traffic. Because the Soviet figure includes the effects of relatively high cost steam locomotive operations, however, it is likely that the Soviet figure should be somewhat lower for diesel and electric operations.

V. Impact of the Electrification and Dieselization Programs.

A. Impact on the Railroad Sector.

Electrification and dieselization of the Soviet railroads have required significant investment in auxiliary facilities to permit taking full advantage of the potential benefits of these types of motive power. These investments, however, can be written off in a few years by savings which accompany full utilization of the potential of electric and diesel locomotives. Some of these improvements would also have improved operation with steam locomotives.

1. Effect on Investment in Line and Auxiliary Facilities.

The superior tractive effort and performance of electric and diesel locomotives compared with steam locomotives permit the hauling of significantly heavier and longer freight trains at higher speeds. To take full advantage of the greater tractive effort of these locomotives, it is necessary to lengthen sidings and yard tracks. By 1960, station tracks on some lines are to be lengthened from the present 850 meters to 1,050 meters. 213/

On the Ordzhonikidze system, where TE-2 diesels partially replaced the type L steam locomotives in 1956, siding and yard tracks did not have to be lengthened, because the locomotives pull trains of approximately equal tonnage and length. When TE-3 diesels are put into service, however, present siding lengths will prevent them from using more than half their rated power until the sidings are increased from 850 to 1,050 meters. 214/ On some lines, where electric trains are expected to pull trains of up to 8,000 tons gross weight, station tracks will be lengthened to not less than 1,500 meters. 215/ On the basis of car lengths it is estimated that an 8,000-ton train would require station tracks 1,800 meters long.

The planned increase in freight and passenger train speeds will require the installation of heavier rails and stone ballast. Rail which is removed to make way for the heavier types is used on main lines which have light traffic density either to replace worn-out rail of the same weight or to replace lighter weights, or it may be used in yards and sidings. It is unlikely that there will be any significant increase in the amount of rail delivered for scrap as a result of installation of heavier types of rail, because most of the lighter rail replaced by these programs is absorbed by the increased track mileage resulting both from construction of new lines and from the expansion of yards and sidings.

On branch lines, or main lines with relatively light traffic, the introduction of diesels may not make it necessary to install heavier rail, because diesel locomotives have lighter axle loadings per unit of tractive effort and do not pound the rails as do steam locomotives. In addition, the rate of replacement of existing rails is reduced because diesels cause less wear. 216/

Although most models of diesel and electric locomotives pull longer, heavier trains than steam locomotives of equal weight, it is generally not necessary to strengthen bridges. Diesel and electric locomotives have lighter axle loads per unit of horsepower; therefore, they may use bridges which steam locomotives could not safely use.

Soviet sources point out that the electrification and dieselization of rail lines should be preceded by various other improvements, such as electric centralization of switches, improved types of signaling, and automatic train stopping devices, 217/ because the higher speeds of these types of motive power require additional safety measures. Electric centralization of switches apparently means electrification of interlocking plants at yard entrances and exits and at junctions and crossing with other lines. Installation of improved types of signalling includes automatic block on double-track lines or centralized traffic control (apparently called "dispatcher centralization" by the USSR) on single-track lines.

Another investment being made to increase the usefulness of diesel and electric locomotives is the installation of radios. In March 1956 it was announced that radios would be installed on TE-3 locomotives produced at the Khar'kov plant. 218/

Although on some lines the introduction of diesels requires additional capital investment for track, signals, and communications to permit full utilization of their potential, on other lines the introduction of diesels, through their added power and flexibility, may postpone or make unnecessary the heavy expenditures required to increase line capacity through either double tracking or the installation of centralized traffic control. For example, on most sections of the Tashkent, Ashkhabad, Orenburg, and Turkestan-Siberian systems the introduction of diesel locomotives and related increases in train weights and speeds have permitted these systems to cope with growing freight traffic without increasing the number of trains. 219/

One of the effects of the installation of facilities discussed above is that, after the initial investment has been made, operating and maintenance costs will be reduced. For example,

installation of heavier rail will result in lower maintenance costs. Few additional investments may be required on lines with light traffic density. In fact, the scrapping of existing facilities for steam power would produce additional income. On most lines, however, to benefit from the higher speed and heavier train potential of diesel and electric locomotives, higher standards of trackage, longer sidings, and improved signaling are a minimum requirement.

2. Effect on the Locomotive Park.

General introduction of diesel and electric locomotives will eventually permit large numbers of steam locomotives to be scrapped or placed in reserve. A Soviet source reports that the 2,000 electric locomotives plus the 2,250 diesel locomotives to be built in 1956-60 will equal -- apparently in terms of total horsepower -- approximately 15,000 type E or 10,000 type FD steam locomotives. 220/ Thus 1 electric or diesel locomotive replaces approximately 2.3 to 3.5 steam locomotives in terms of horsepower alone. The greater availability of diesel and electric locomotives compared with steam locomotives, which results from a reduction in delays for fuel and water stops and from shorter servicing and repair time, may cause this ratio to be even higher.

The scrapping of steam locomotives will involve a credit to the railroads for scrap iron and steel. As yet, there is no direct evidence that the USSR is scrapping steam locomotives other than those involved in normal retirements. As steam locomotives are replaced on individual lines by diesel and electric locomotives, the USSR is using the newer model steam locomotives to replace older models on other lines. For example, some of the World War II type E locomotives which the USSR imported from the US and Canada and used on the Omsk-Novosibirsk line apparently have been sent to the systems of the Far East. In the Far East they have been displacing the World War I type E locomotives imported from the US. It is assumed that the older models are being scrapped or held in reserve. The 31,800 steam locomotives (freight, passenger, and switcher) estimated to be in operation at the end of 1956 contain an estimated total of 4.8 million tons of metal (using a rough average of 150 tons per locomotive and tender).

3. Effect on Repair and Servicing Facilities.

Soviet steam locomotives require water approximately every 40 km and coal approximately every 80 km. 221/ The normal Soviet practice is to have steam locomotives based at a home terminal where they receive running repairs, boiler washing, and perhaps medium repairs. The locomotives make runs of from 80 to 175 km from the home terminal to a turnaround point, where they are serviced and given

necessary light repairs, and then return to their home terminal. There are large roundhouses or locomotive sheds at home terminals and smaller sheds at turnaround points. Capital repairs of steam locomotives are performed at a few large locomotive factories which serve large areas.

Diesel and electric locomotives require no boiler water and only very small quantities of water for other uses. Diesels run about 800 km between refuelings. 222/ Electric locomotives require no fueling facilities. Fueling of diesel locomotives requires only simple facilities at a small number of points compared with steam fueling facilities. On at least one line it appears that diesel locomotive home terminal sheds are located approximately 1,100 km apart. Thus diesels run 550 km from two home terminals to a common turnaround point and 550 km back. The watering and coaling facilities for steam locomotives, therefore, can be abandoned on electrified and dieselized lines, and many of the steam locomotive sheds and roundhouses can be dismantled. Although steam locomotive sheds and roundhouses may be rebuilt for use by diesels, it is often preferable to abandon existing sheds and roundhouses and to build new sheds specifically designed to handle repairs typically encountered with electric or diesel locomotives.

By the end of 1960, steam locomotive repair factories at Tashkent, Voronezh, and Chkalov are to be converted to diesel repairs, and the Astrakhan' plant is already performing diesel repairs. The Novosibirsk, Zaporozh'ye, and Ulan-Ude steam locomotive repair plants will be rebuilt by the end of 1960 to repair electric locomotives; the Tbilisi plant already repairs electric locomotives; and a new plant is under construction at Chelyabinsk. 223/

4. Effect on the Amount of Coal Hauled for Locomotive Fuel.

One of the major effects on the railroads which will result from the electrification and dieselization programs is that the amount of coal hauled by railroads for their own use will be drastically reduced. Soviet railroads consume 25 to 30 percent of all coal mined in the USSR (see D, p. 68, below). Diesel locomotives consume only from 10 to 12 percent of the tonnage of fuel consumed by steam locomotives for hauling equal amounts of traffic. Freight hauled by an individual Soviet railroad system for its own use is not included in either the tonnage or the ton-kilometer figures, which normally represent only revenue freight. The coal formerly used as fuel for steam locomotives and not recorded as revenue freight will instead move as revenue freight and be consumed by industry. Thus during the period of power changeover the tonnage and ton-kilometers of coal hauled as revenue freight should show a

moderate increase over and above normal increases, although there will not be a significant effect on the tonnage actually hauled by the railroads. The effect of this diversion of coal from railroad to industry use as a result of electrification is shown in Table 18.

Table 18

Coal Consumption and Savings Resulting from Electrification of Soviet Railroads a/
1955 and 1960, 1965, and 1970 Plans

Million Tons

	1955	1960 Plan	1965 Plan	1970 Plan
Amount of coal required to produce electric power for railroads (required for electric traction which is planned), excluding hydroelectric power	2	7	15	21
Amount of coal required by railroads if traffic to be hauled by electric locomotives were carried by steam locomotives	8	32	74	108
Coal saved by use of electric locomotives	6	25	59	87

a. 224/

In addition, this diversion of coal from railroad to industry is to reduce the average distance which coal will have to be hauled from 688 km in 1955 to between 610 and 630 km in 1960. This anticipated reduction is not to be caused entirely by electrification, because the use of gas for heating purposes is increasing in the USSR and will make unnecessary some of the longer coal hauls. Industrial dislocations, however, appear to be offsetting this gain, and the average length of coal haul is actually increasing. 225/

In addition to the savings in the hauling of fuel coal for railroads resulting from electrification, there will be even greater coal savings resulting from dieselization because when diesel locomotives are introduced, all locomotive fuel coal is replaced by diesel oil.

5. Effect on Other Freight for Railroad Use.

Because steam locomotives require large quantities of boiler feed-water, the introduction of diesel locomotives in some desert areas has significantly reduced the amount of water hauled by rail for railroad use. In Central Asia, for example, it is common to see a steam engine pulling a train of from 23 to 26 cars, of which about one-fourth consist of tank cars of water to be delivered to steam locomotive water supply points which have an insufficient supply of water. 226/ The useful load of trains on such lines was considerably reduced by the necessity of carrying so many tank cars of water.

6. Effect on Personnel.

A large training and retraining program in the operation and repair of diesel and electric locomotives has had to be instituted for railroad personnel. In 1956-60, training will be required for nearly 16,000 locomotive engineers, 30,000 engineer helpers, more than 10,000 skilled repairmen, and hundreds of engineers and technicians for diesel traction alone. 227/

At the same time, the number of operating and repair personnel can be reduced because of the improved performance of these types of motive power, the smaller number of locomotives required to perform the same amount of work as with steam power, and the smaller amount of repair time required. Electrification of railroads is stated to result in a 25-percent reduction of personnel (believed to be based on ton-kilometer performance per worker) compared with the operation by steam locomotives. 228/ Similar reductions undoubtedly result from the introduction of diesel locomotives. One Soviet source says that 100 men are released for other jobs for every 100 km of track which is converted to electric or diesel traction. 229/ This estimate is believed to be based on the assumption that the levels of traffic are equal. A Soviet article on the electrification of the Khar'kov-Merefa line stated that the change will permit a reduction of locomotive crews by 30 percent and repair crews (apparently locomotive repair crews), by 50 percent. 230/

An indication of the effects of electrification and dieselization on personnel requirements and productivity compared with operation with the type FD steam locomotive is shown in Table 19.*

* Table 19 follows on p. 65.

Table 19

Reductions in Personnel Costs and Numbers
and Increases in Productivity with Electric and Diesel Operation
Compared with Type FD Steam Locomotives a/

	Percentage Change Compared with Type FD Steam Locomotives		
	VL-22m Electric	N-8 Electric	TE-3 Diesel
Reduction in expenditures for maintenance of operating crews (locomotive and train crews)	50	33	50
Reduction in working contingent b/	27	40	30
Reduction of entire working contingent c/	9	13	10
Increases in labor productivity for entire working contingent c/	10	15	11
Increases in labor productivity b/	37	67	43

a. 231/. The type FD is the most powerful Soviet freight locomotive.
b. Believed to include only the train operating crews.
c. Believed to include both train operating crews and locomotive repair personnel but may also include track maintenance personnel.

B. Impact on the Electric Power Industry.

The plan for electrification of 40,000 more km of line during the 15-year period 1956-70 will increase the consumption of electric power by electric traction from 3 billion kwh in 1955 to 48 billion kwh in 1970. Data on the consumption of electric power by rail transport as a whole and by electric traction alone for 1955 and the 1960, 1965, and 1970 plans are presented in absolute figures and in percentages in Table 20.*

* Table 20 follows on p. 66.

Table 20

Estimated Consumption of Electric Power by Railroads in the USSR a/
1955 and 1960, 1965, and 1970 Plans

	Billion Kilowatt-Hours				Percentage Distribution			
	1955	1960 Plan	1965 Plan	1970 Plan	1955	1960 Plan	1965 Plan	1970 Plan
Total output of electric power in the USSR	170	320	600-650	750-1,000	100.0	100.0	100.0	100.0
Total electric power consumption by railroad transport as a whole	6.65	18	40	60	3.9	5.6	6.2-6.7	6.0-8.0
Electric power consumption by electric traction alone	3	13	30	48	1.8	4.1 b/	4.6-5.0	4.8-6.4 b/

a. 232/
b. Computed from data in kilowatt-hours.

Additional power is consumed by rail transport for purposes other than the operation of electric traction. Total consumption of electric power for all railroad purposes amounted to 6.65 billion kwh in 1955, or 3.9 percent of the total output of electric power in the USSR. In 1960, consumption is expected to amount to 18 billion kwh, or 5.6 percent of total output of electric power in that year. In 1957, rail transport is expected to consume 9.2 billion kwh of electricity. Production of electric power by railroad powerplants in 1957 is planned at 1,535 million kwh, or 17 percent of anticipated rail consumption. 233/

Electrification of railroads requires the installation not only of the catenary but also of considerable mileages of high-voltage transmission lines to carry the power over long distances. In addition, it is necessary to build substations to step the voltage down and convert alternating current to direct current for transmission to the catenary. During 1956-60 it will be necessary to install about 6,500 km of high-voltage power lines for the rail electrification program, 234/ or 13 percent of the 50,000 km of main high-voltage power transmission lines to be strung during this period. 235/ The cost of installing high-voltage power lines may be estimated roughly at 110,000 rubles per kilometer (based on a Soviet source which states that a 110-kw line costs 95,000 to 120,000 rubles to install). 236/ The total cost of installing the 6,500 km for rail electrification, therefore, would be about 715 million rubles. The cost of building the required number of substations is estimated roughly at an additional 160 million rubles. In addition, it is estimated that 200,000 kw of new generating capacity will need to be built at an average cost of 1,500 rubles per kilowatt, or a total cost of 300 million rubles. Thus the total cost for transmission lines, substations, and generating facilities is estimated at 1,175 million rubles.

C. Impact on the Petroleum Industry.

Until recent years the use of petroleum fuels by railroads in the USSR was limited. In fact, the only known use of fuel oil by steam locomotives was in the Caucasus area. Aviation and shipping, both civilian and military, as well as the expanding truck and tractor parks, always ranked ahead of the railroads in petroleum fuel priorities. Therefore, the adoption of diesel locomotives was limited to those systems located close to sources of liquid fuel or to those experiencing difficulties in supplying water or coal for steam locomotives. Unforeseen production of the Ural-Volga oilfields, however, has caused Soviet planners to place dieselization of rail-lines virtually on a par with electrification.

The increasing share of total freight hauling to be performed by diesel locomotives in the immediate future will cause a significant increase in the consumption of diesel fuel by the railroads. Whereas total production of diesel fuel in the USSR is to increase by 88 percent from 1955 to 1960, consumption of this fuel by railroads will increase by 466 percent. As a result, consumption of diesel fuel by railroads will rise from about 3.8 percent of total production in 1955 to 11.6 percent in 1960. Thus Soviet railroads are rapidly becoming a substantial customer of the growing Soviet petroleum industry. Estimated consumption of diesel fuel by Soviet railroads and the percentage of total Soviet diesel fuel consumed by railroads for 1950, 1955, and the 1960 plan are shown in Table 21.*

D. Impact on the Coal Industry.

Stated plans for the dieselization and electrification of the Soviet railroad system will change the status of the railroads from a major customer of the coal industry -- about 25 percent of the total coal produced in the USSR in 1954 -- to a consumer of only about 3 percent of the total coal produced in 1970.

Many statements have been made by Soviet economists and engineers pointing out the great savings in coal consumption that will be effected by the changeover to diesel and electric traction (see V, A, 4, p. 62, and Table 18, p. 63, above). Because of the greater efficiency of central power stations, consumption of coal is 50 to 60 percent less than that used by steam locomotives. 237/ It is believed that this figure is based on standard fuel. The saving may be somewhat less in terms of tonnages of actual fuel because central power stations can use lignite, peat, and oil shales which cannot be used as efficiently by steam locomotives as can higher grade coals. This utilization of lower grade fuels not only will result in lower cost, however, but also will tend to reduce the average length of haul because local fuels can be used. 238/ When power comes from hydroelectric plants, coal consumption is reduced 90 to 95 percent compared with the requirements for steam locomotives. 239/ The combined effect of thermal electric and hydroelectric powerplants is to reduce fuel consumption per unit of traffic to one-third or one-fourth of that of steam locomotives. 240/ A total of 30 million tons of coal should be saved per year from electrification and dieselization. 241/

About 80 percent of the coal used by the Soviet railroads (apparently in 1954-55) was burned in steam locomotives. 245/ According to plan, gradual retirement of steam locomotives will

* Table 21 follows on p. 69.

Table 21

Estimated Consumption of Diesel Fuel by Soviet Railroads
1950, 1955, and 1960 Plan

Year	Estimated Ton-Kilometers of Freight Performed by Diesel (Billions)		Estimated Consumption of Diesel Fuel by Diesel Freight Locomotives a/ (Thousand Metric Tons)	Estimated Total Consumption of Diesel Locomotive Fuel by Railroads b/ (Thousand Metric Tons)	Estimated Total Production of Diesel Fuel c/ (Million Metric Tons)	Percentage of Total Production Consumed by Railroads for Locomotive Fuel
	Net d/	Gross e/				
1950	13.2	24.0	86	103	3.6	2.9
1955	53.4	97.1	348	418	10.9	3.8
1960 plan	302.0	549.1	1,977	2,372	20.5	11.6

a. Calculated on the basis of 3,600 metric tons of diesel fuel consumed per billion gross ton-kilometers. Fuel consumption is estimated at 50 kg per 10,000 gross tkm in terms of standard fuel. 242/ Because the ratio of standard fuel to actual fuel is estimated at about 1.4 to 1, 243/ actual diesel fuel consumption is estimated at about 36 kg per 10,000 gross tkm or 3,600 metric tons per billion gross tkm.
b. Switching, passenger service, and other operations are estimated to consume 20 percent as much fuel as do freight locomotives.
c. 244/
d. See Table 2, p. 10, above.
e. Gross ton-kilometers are estimated to be 182 percent of net ton-kilometers.

eliminate this requirement by 1970. The substitution of oil and gas for some nonoperational requirements should also tend to lower the total railroad requirement for coal. The increasing demand for electric power from thermal electric plants, however, will require more coal as the amount of work performed by electric traction becomes greater. The net result will be a substantially lighter demand by the railroads on the coal industry both in absolute terms and as a percentage of total Soviet coal production. More coal, therefore, will be available to feed the furnaces of expanding Soviet industrial complexes.

The estimated demands for coal by Soviet railroads for 1954-55 and the 1960, 1965, and 1970 plans are shown in Table 22.* Because of the reduction in demand for coal by the railroad industry, during the Sixth Five Year Plan there is to be a reduction of from 3 billion to 3.5 billion rubles in capital investment for expansion of the coal industry and for improvement in the management of steam locomotives. 246/

* Table 22 follows on p. 71.

Table 22

Estimated Demands for Coal by Soviet Railroads
1954-55 and 1960, 1965, and 1970 Plans

Year	Ton-Kilometers Performed by Steam Locomotives a/ (Billions)	Coal Requirements for Steam Locomotives b/ (Million Tons)	Ton-Kilometers by Electric Operation a/ (Billions)	Coal Requirements for Electric Operation (Million Tons)	Other Railroad Coal Requirements c/ (Million Tons)	Total Railroad Coal Requirements (Million Tons)	Total Coal Production d/ (Million Tons)	Railroad Share of Total Coal Production (Percent)
1954	769.4	70.6	54.0	1.7 e/	14.5	86.8 f/	347.1	25 g/
1955	835.0	81.0	82.5	2.5 e/	14.3	97.8 f/	391.3	25 h/
1960 plan	783.0	86.9	289.0	7.0 i/	7.0	100.9	575.0	18
1965 plan	273.0	25.9	781.5	15.0 i/	3.5	44.4	750.0	6
1970 plan	0	0	1,267.8	21.0 i/	2.0	23.0	850.0	3

a. From Table 2, p. 10, above.
b. The 1954 figure is based on a Soviet statement that 70.6 million tons of coal were burned by steam locomotives in 1954, 247/ and performance of 769.4 billion net tkm by steam locomotives in 1954, which gives an average consumption of 91,800 tons of coal per billion ton-kilometers in 1954. The consumption rates for 1955, 1960, and 1965 are based on estimates of the amount of coal which would be required to perform the ton-kilometers estimated to have been performed by electric locomotives in Table 18, p. 46, above. This gives consumption per billion ton-kilometers as follows: 1955, 97,000 tons; 1960, 111,000 tons; and 1965, 95,000 tons.
c. Calculated on the basis of 1954 coal consumption by steam locomotives of 70.6 million tons, by electric operations of 1.7 million tons, and a calculated total requirement by railroads of 86.8 million tons (based on 25 percent of total coal production). The balance coal requirements for railroads in 1954 is therefore 14.5 million tons, or about 4 percent of total Soviet production. This would include coal for heating, and power for shop use and other purposes. The 1955 balance after other requirements is 14.3 million tons. Because fuel for these purposes will probably be met more by gas and oil in the future, this requirement is estimated as being cut roughly in half (in terms of tonnage) in each fifth year after 1955.
d. Estimated.
e. According to a statement by a Soviet economist, A. Chertkov, 248/ "70.6 million tons of coal were burned by steam locomotives in 1954, while 23 million tons would haul the same amount via electric power plants and electrified railroads." An average of 91,800 tons of coal per billion ton-kilometer therefore was consumed by steam operation. Electric operation would have required about 33 percent of this amount for the same work. The number of ton-kilometers performed by electric locomotives therefore is multiplied by 91,800 tons, and 33 percent of this product is taken to be the estimated coal requirement for electric operations in 1954 and 1955.
f. Based on announced percentages shown in last column.
g. 249/
h. 250/
i. 251/. See Table 18, p. 46, above.

APPENDIX A

LIST OF RAILROAD LINES ELECTRIFIED IN THE USSR AS OF 31 DECEMBER 1955 AND FUTURE PLANS FOR ELECTRIFICATION

This appendix lists the railroad lines electrified in the USSR as of 31 December 1955 and future plans for electrification during 1956-60 and 1961-70. Totals of the first two columns do not agree precisely with figures in Table 1* for reasons shown in appropriate footnotes. The total of the third column when added to the totals of the first two columns equals only 26,415 km compared with the plan to have 45,500 km of track electrified by 1970. This great difference is caused by the fact that the USSR has not released specific information on many of the lines to be electrified in 1961-70.

* P. 6, above.

Lines Electrified as of 31 December 1955	Length a/	Additional Electrification 1956-60	Length a/	Additional Electrification 1961-70	Length a/
Trans-Siberian main line (including European section)					
Moscow-Ramenskoye b/	44	Ramenskoye-Inza-Bezymyanka c/	1,062	Slyudyanka - Ulan-Ude	331
Bezymyanka-Smyshlyayevka e/	11	Smyshlyayevka-Dema	492		
Dema-Chelyabinsk f/	490	Chelyabinsk - Kurgan - Isil'-Kul'	660	Petrovskiy Zavod - Vladivostok d/	3,507
Isil'-Kul' - Omsk g/	138	Novosibirsk-Irkutsk c/	1,851		
Omsk-Novosibirsk h/	627	Ulan-Ude - Petrovskiy Zavod i/	143		
Irkutsk-Slyudyanka j/	134 k/				
Total	1,444		4,208		3,838
Siberian branch lines of Trans-Siberian					
Belovo-Novokuznetsk (Stalinsk) h/	141	Inskaya-Promyshlennaya-Belovo c/	289	Barnaul-Omsk (new line) l/	750 m/
Novosibirsk-Inskaya f/	19	Omsk-Nazyvayevskaya n/	149	Inskaya-Barnaul o/	209
				Barnaul-Kulunda p/	343
Total	160		438		1,302
Other main lines to the East					
Moscow-Aleksandrov f/	113	Aleksandrov-Vspol'ye c/	170	Vspol'ye-Yaroslavl'-Kirov-Perm' d/	1,155
Moscow-Zheleznodorozhnaya f/	24	Zheleznodorozhnaya-Fryazevo-Noginsk g/	44	Fryazevo-Petushki-Gor'kiy-Kotel'nich c/	755
Total	137		214		1,910
Urals lines not included elsewhere					
Sverdlovsk-Nadezhdinsk (Serov) h/	388	Chelyabinsk-Sverdlovsk n/	252		
Nadezhdinsk (Serov)-Bogoslovsk (Karpinsk) r/	48				
Goroblagodatskaya-Perm' h/	312	Kizel-Perm' (new line) n/	160 s/	Perm'-Sverdlovsk c/	381
Chusovaya-Usol'ye h/	205	Magnitogorsk-Abdulino (new line) n/	540 t/	Sinarskaya-Krasnoufimsk l/	320 y/
Usol'ye-Solikamsk r/	27				
Berdyaush-Bakal f/	52				
Total	1,032		952		701
Moscow-Khar'kov-Donbas					
Moscow-Serpukhov f/	99	Serpukhov-Khar'kov-Donbas (Slavyansk) c/	933	Slavyansk-Rostov d/	319

Lines Electrified as of 31 December 1955	Length a/	Additional Electrification 1956-60	Length a/	Additional Electrification 1961-70	Length a/
Other Moscow-Donbas-Caucasus connection					
Moscow-Ozherel'ye-Mikhaylov f/	209	Mikhaylov-Pavelets f/	52		
		Likhaya-Bataysk y/	174	Ryazhsk-Likhaya n/	766
				Bataysk-Armavir-Belorechenskaya n/	404
Total	209		226		1,170
Other Donbas and Krivoy Rog line					
Krivoy Rog - Dolgintsevo - Zaporozh'ye w/	202 w/	Pyatikhatki-Yasinovataya c/	382		
Caucasus and Trans-Caucasus lines					
Akstafa-Tbilisi-Sukhumi f/	499 x/	Sukhumi-Sochi-Belorechenskaya c/	347		
Alabashly - Kushchinskiy Most r/	35	Kirovabad-Akstafa y/	94		
Takhakaya-Poti h/	40	Zestafoni-Chiatura (new line) z/	36 z/		
Ochemchiri-Kvezani aa/	27				
Samtredia-Batumi h/	106				
Sanain-Leninakan h/	110			Leninakan-Yerevan n/	154
Tkibuli-Rioni bb/	59				
Khashuri-Borzhomi h/	30				
Kislovodsk - Mineral'nyye Vody h/	64			Armavir - Mineral'nyye Vody d/	188
Beshtan-Zheleznovodsk f/	6 cc/				
Baku-Sumgait r/	30				
Baku-Buzovny f/	25 x/				
Sabunchi-Surakhani f/	7 x/				
Total	1,038		477		342
Other Moscow and Leningrad lines					
Moscow-Iksha r/	45	Iksha-Dmitrov dd/	20		
Moscow-Klin c/	89	Klin-Kalinin c/	78	Kalinin - Malaya Vishera d/	322
Tosno-Leningrad ee/	53	Malaya Vishera - Tosno ff/	109		
Leningrad-Sestroretsk-Beloostrov gg/	43 cc/				
Leningrad-Pavlovsk hh/	27				
Leningrad-Lomonosov (Oranienbaum) r/	40				
Ligovo-Gatchina ii/	33				
Leningrad-Zelinogorsk-Roshchino jj/	60				
		Lyubertsy-Kurovskaya-Cherusty g/	136		
Moscow-Golitsyno c/	44	Golitsyno-Mozhaysk c/	66		

Lines Electrified as of 31 December 1955	Length a/	Additional Electrification 1956-60	Length a/	Additional Electrification 1961-70	Length a/
Other Moscow and Leningrad lines (Continued)					
Moscow-Aprelevka c/	42	Aprelevka-Maloyaroslavets c/	79		
Moscow-Novoiyerusalimskaya f/	61	Novoiyerusalimskaya-Volokolamsk c/	65		
Reutov-Balashikha f/	12 cc/				
Mytishchi-Monino f/	31 cc/				
Total	580		553		322
Leningrad and Moscow connections with Vorkuta					
				Leningrad-Vologda kk/	600
				Danilov-Vologda-Konosha-Kotlas-Vorkuta	1,913
Total	0		0		2,513
Baltic Republic lines					
Riga-Kemeri h/	45				
Tallinn-Pyaskyula ll/	11				
Total	56				
Kola Peninsula					
Murmansk-Kandalaksha f/	278	Kandalaksha-Loukhi mm/	167		
Apatity-Kirovsk f/	22				
Total	300		167		
Carpathian region					
		Mukachevo-Lavochne nn/	79		
Other suburban					
		Kiev-Darnitsa oo/	14		
		Kiev - Belaya Tserkov pp/	98		
				Suburban lines in Riga, Tallinn, Kiev, Khar'kov, Dnepropetrovsk, Stalingrad, Rostov, Sochi, Sukhumi, Tbilisi, Kalinin, Gor'kiy, Molotov, Sverdlovsk, Kuybyshev, Ufa, Chelyabinsk, Omsk, Novosibirsk, Irkutsk, and others n/	N.A.
Total	0		112		N.A.
Grand total	5,257 qq/		8,741 rr/		12,417 ss/

a. From official timetables 252/ unless otherwise specified. These figures, therefore, represent route-kilometers rather than track-kilometers.
b. 253/
c. 254/
d. 255/
e. Put in operation in 1951. 256/
f. 257/
g. Included by the USSR among lines completed in Fifth Five Year Plan rather than among 1956 lines, 258/ even though it did not go into permanent operation until April 1956. 259/ Electrification was basically completed in 1955, but the temporary power line across the Irtysh had to be replaced by a permanent one. 260/
h. 261/
i. Although no other source reported planned electrification beyond Slyudyanka in the 1956-60 period, a recent broadcast stated, in discussing plans for work in 1956: "It is planned to begin the electrification of the Ulan-Ude - Petrovskiy Zavod road. In the not too distant future electric locomotives will be running there." 262/
j. Believed to be officially included in lines electrified during the Fifth Five Year Plan, although not in operation until 1956. Steel posts were up and the catenary was strung as of December 1955. 263/ The line was not included among the 847 km publicized as the plan for 1956. 264/ However, it did not go into operation until April 1956. 265/
k. 266/
l. Construction of the Sinarskaya-Krasnoufimsk line is to be completed during 1956-58, and one source reports that electric locomotives will operate over it. The Barnaul-Omsk line is also to be built during the 1956-60 period, and the same source states: "The road bed must be sturdy enough to withstand the movement of electric locomotives hauling trains having gross weights of up to 8,000 tons." 267/
m. 268/
n. 269/
o. 270/
p. 271/
q. 272/
r. 273/
s. 274/
t. 275/
u. 276/
v. 277/
w. 278/
x. Distance estimated from large-scale maps.
y. 279/
z. 280/
aa. Source merely refers to the electrical line Ochemichiri-Kvezani (Tkvarcheli) 281/; so there is a slight possibility the line was electrified after 1 January 1956. One source stated, "Passenger traffic will be started soon on the electrified branch railroad Kvezani-Akarmara." 282/ This line is not a new line as might be inferred. Akarmara is an alternate name for Kvezani.
bb. 283/
cc. 284/
dd. First electric train ran on Iksha-Dmitrov stretch on 5 July 1956. 285/
ee. Only one of the tracks was electrified as of 1949. 286/
ff. 287/
gg. 288/
hh. 289/
ii. 290/
jj. 291/
kk. 292/
ll. 293/
mm. One radiobroadcast said that it was planned to commission this electrified stretch in 1958. 294/ However, a map in a recent Soviet publication showed this stretch planned for dieselization rather than electrification. 295/
nn. 296/

oo. 297/
pp. 298/. Construction of this new electrified railway has begun. 299/ Distance is approximate.
qq. The estimate of total electrified line in 1955 as shown in Table 1 (p. 6, above) is 5,400 km, of which only 5,257 could be identified in this tabulation. The difference could stem from differences in kilometrage of individual lines as given in various Soviet sources and from the omission, from Soviet maps and other sources, of a number of minor electrified lines.
rr. A total of 13,500 km of electrified line is to be completed by 1960. The 8,741 km shown in this list to be electrified in this period, plus the 5,257 km identified as being electrified at the end of 1955, give a total of 13,998 km. This excess could result from differences in kilometrage of individual lines as given in various Soviet sources, from the length of some recently constructed lines having to be estimated, and from the inclusion of lines not included in the original announcement of 1960 goals.
ss. The 12,417-km total shown here for the 1961-70 period, plus the 13,992 km shown in the other two columns of this list, gives a total length of identified lines of 26,409. It is planned to have 45,500 km of track electrified by 1970 (see Table 1, p. 6, above). The difference in the two figures results from the fact that the USSR has not yet identified all lines planned to be electrified by 1970.

APPENDIX B

BASIC CHARACTERISTICS AND DEVELOPMENTAL TRENDS OF DIESEL AND ELECTRIC LOCOMOTIVES USED IN THE USSR

The main body of this report has discussed many of the advantages inherent in the dieselization and electrification of programs in the USSR and the factors which probably motivated the launching of these programs.

Soviet diesel and electric locomotives are considerably more productive than steam locomotives. Soviet engineers estimate that 1 VL-22m electric locomotive, in terms of over-all work productivity, replaces 3 type E or 2 type FD steam locomotives. The new N-8 electric, VL-23 electric, and TE-3 diesel locomotives will be even more effective. The 2,000 electric and 2,250 diesel locomotives to be constructed during 1956-60 will be equal in power to approximately 15,000 type E or 10,000 type FD steam locomotives. 300/

On straight and level track, N-8 electric locomotives can operate a train weighing 4,000 tons at a running speed of 85 km per hour. A TE-3 diesel locomotive can do the same at 67 km per hour, whereas the speed of the type FD steam locomotive, operating under identical conditions, does not exceed 63 km per hour. 301/

1. Diesel Locomotives.

There are three major types of diesel locomotives in the USSR, designated TE-1, TE-2, and TE-3* (TE is the abbreviation for "teplovozy electroperedachey," or internal combustion locomotive with electric drive). The basic characteristics and total estimated production through 1956 of each of these three types is shown in Table 23.** The TE-1 is a road-switcher type of freight locomotive with a box-like profile and is generally operated as a single unit. The TE-2 and TE-3 are streamlined main-line freight locomotives which generally operate with two units coupled together.

* See Figures 7, 8, following p. 80.
** Table 23 follows on p. 80.

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Table 23

Basic Characteristics and Total Estimated Production Through 1956 of Major Types of Diesel Locomotives Used in the USSR a/

	TE-1	TE-2 b/	TE-3 b/
Year first unit was produced	1947	1948	1953
Number of axles per unit	6	4	6
Total weight with full load of fuel, water, lubricants, and sand (metric tons)	124	83 c/	126
Designed (maximum) speed (km/hr)	90	93	100
Effective horsepower d/	1,000	1,000	2,000
Total estimated production through 1956 e/	301 f/	548 g/	164 h/

a. 302/
b. Although these types normally run with two units coupled together, these figures are for individual units.
c. Source gives figure of 166 tons, which is weight of two units coupled together.
d. A Soviet source shows that these figures are the power of the diesel engine, but the useful power of a 2-unit TE-2 locomotive is 1,530 hp and of a 2-unit TE-3 locomotive 3,600 hp. 303/ The latter figure apparently considers losses between the diesel engine and the electric traction motor.
e. 304/
f. Including two units modified for cold weather operation and designated TE-5.
g. Figures for the TE-2 are in terms of 2-unit locomotives totaling 2,000 hp. Hence production of individual TE-2 units totaled 1,096 units. Two individual TE-2 units included in this total were utilized in the 1 TE-4 locomotive which was produced.
h. Figures for the TE-3 are in terms of single 2,000-hp units although they operate as 2-unit locomotives. The figures include a few units designated TE-7 modified for passenger and express freight service.

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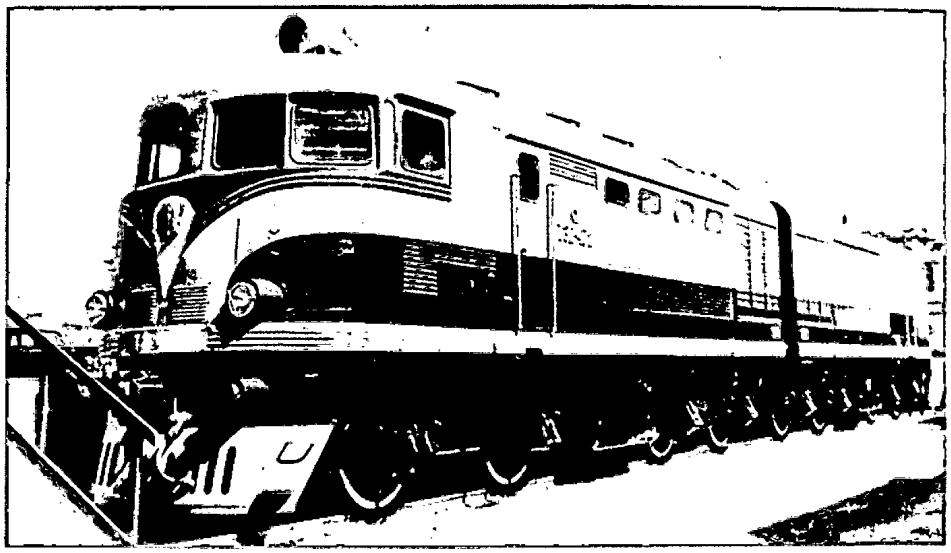

Figure 7. USSR: Two-Unit TE-2 Diesel Locomotive, 1955. [The USSR is estimated to have produced 274 of these 2,000 hp Locomotives (1,000 hp per unit) through 1956.]

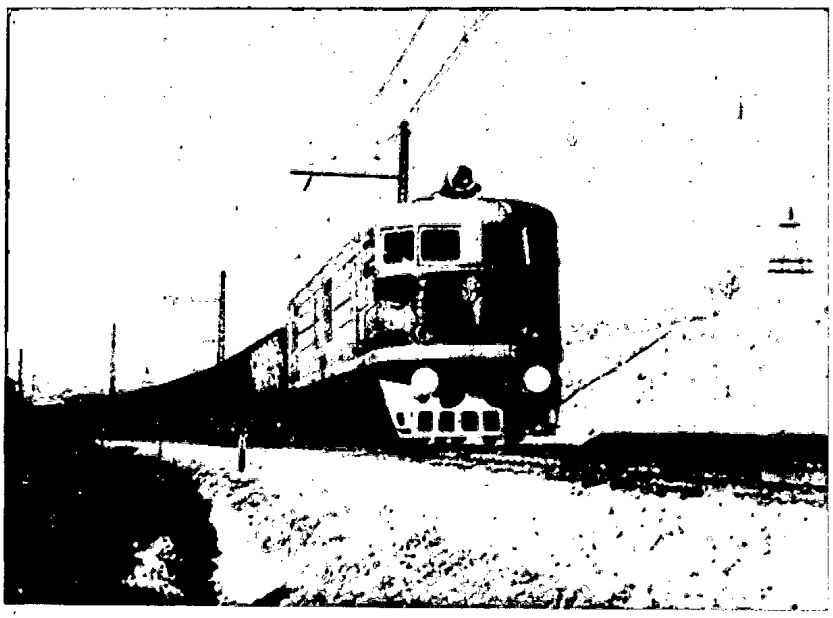

Figure 8. USSR: Two-Unit TE-2 Diesel Locomotive, Probably Early 1950.
(Note that this test line is also electrified.)

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2. Electric Locomotives.

The basic characteristics and total estimated production through 1956 of the major types of electric locomotives used in the USSR are shown in Table 24.* As indicated in this table, the locomotive used preponderantly in the USSR is the VL-22m.** The VL-22m is now being supplemented and eventually will be replaced by the VL-23 and the N-8.*** The VL-23 is designed for high-speed, level-country operation, and the N-8 is designed primarily for operation over steep grades.

3. Developmental Trends.

The USSR has produced several experimental locomotives in the postwar period. One of these is the TE-4, which consists of two TE-2 units separated by a gas-generator unit. The generator produces a gas from coal, and the diesel engines operate on either diesel fuel or a mixture of 75 percent gas and 25 percent diesel fuel. 305/ Experiments are still being conducted with gas-operated diesels.

The new high-speed diesel passenger locomotive, designated TE-7, is now in production. This model appears to be exactly the same as the TE-3 with two 2,000-hp units per locomotive, except that it has different gearing to permit higher speeds and modified brakes to permit rapid stops from high speeds. 306/ These locomotives will also be used to pull high-speed freight trains, such as trains hauling perishable goods. 307/

The USSR has also begun production of diesel switch locomotives. During 1956-60, production will begin on diesels of 300 to 400 hp and 700 to 800 hp which have hydraulic-mechanical transmission rather than the electric motors found on main-line locomotives of the TE series. 308/ The first 750-hp diesel switcher, designated TGv, is now in production at the Voroshilovgrad Locomotive Works.**** 309/

In both the US and the USSR, work has progressed on gas-turbine locomotives. In the USSR the Kolomna Locomotive Building Plant is constructing a 6,000-hp, 2-section, single-shaft gas-turbine freight locomotive. The design speed is 100 km per hour, the coupled weight is 278.4 tons, and each section has two 3-axle trucks. This locomotive is designed to pull a 4,000-ton train up a 0.9-percent grade at 30 km per hour. A 340-kw motor is mounted on each axle. The 4-stage gas turbine produces 3,000 hp at 8,500 revolutions per minute (rpm), and the 12-stage compressor increases pressure sixfold. The turbine shaft passest

* Table 24 follows on p. 84.

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**** See Figure 16, following p. 84.

† Continued on p. 84.

Table 24

Basic Characteristics a/ and Total Estimated Production b/ Through 1956 of Major Types of Electric Locomotives Used in the USSR c/

	VL-19 d/	VL-22	VL-22m	N-8	N-0 e/	VL-23
Year first unit was produced	1932	1938	1941	1953	1954	1956
Number of axles per unit	6	6	6	8	6	6
Total weight (metric tons)	117	132 f/	132	180	132 f/	138 f/
Tractive effort, hourly (kg) g/	18,000 19,500 20,000	24,000 20,000	23,900 19,800	35,300	23,400	26,400
Hourly speed (km/hr) g/	37, 39, 43.5	30.5, 36.5	36, 43, 58	42.6	40.5	42.6
Designed (maximum) speed (km/hr) g/	75, 85, 90	70, 85	75, 90	90	85	90
Voltage g/	1,500, 3,000	3,000	3,000	3,000	20,000	3,000
Horsepower	2,760 h/	2,760 h/	3,270 h/	5,700 h/	3,200 i/	4,300 h/
Total estimated production through 1956 (units)	145	38	1,145	20	11	2

a. 310/

Table 24

Basic Characteristics a/ and Total Estimated Production b/ Through 1956
of Major Types of Electric Locomotives Used in the USSR c/
(Continued)

b. 311/
c. Excluding types produced or imported primarily in the prewar period, of which there are only small numbers. These types are as follows: SK, SKh, Ss, S, Si, and PB.
d. Some VL-19 models were modified in 1947 and designated as VL-19m. (See Figures 14, following p. 84.)
e. This is a passenger type of locomotive. All other types in this table are intended primarily for freight service. (See Figure 15, following p. 84.)
f. With ballast.
g. Within any one locomotive type, there are variations in certain performance characteristics resulting from differences in type of electric motors, in gearing, or (as in the case of the VL-19) in voltage.
h. 312/
i. 313/

50X1

through a reduction gear to 3 generators, the over-all capacity of which is 2,200 kw at 1,800 rpm. Meanwhile, the Voroshilovgrad Locomotive Building Plant is building a 6,000-hp, electric-transmission, free-piston engine, gas-turbine locomotive. This 2-section locomotive has 8 free-piston engines. 314/

An atomic locomotive is under discussion in the US as well as in the USSR. Now that considerable information is available on shielding of reactors for the protection of personnel, it appears that railroad clearances are just barely sufficient to accommodate an atomic locomotive with adequate shielding. Soviet engineers reportedly have started a project to develop an atomic locomotive of 8,000 hp. This locomotive is to be in two sections. The first section will contain the reactor, boiler, and protective shield; the second section will contain a steam turbine and auxiliary equipment. The weight of this locomotive is to be 300 tons, and it would use rails of a gauge of 3.0 to 4.5 meters (10 to 15 feet) 315/ compared with the Soviet standard gauge of 1.524 meters (5.0 feet). Advantages of an atomic locomotive are obvious, since there would be no refueling problem. However, possible radiation hazards in servicing as well as in case of wrecks remain strong deterrents to railroad application.

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Figure 14. USSR: VL-19 Electric Locomotive, 1952.

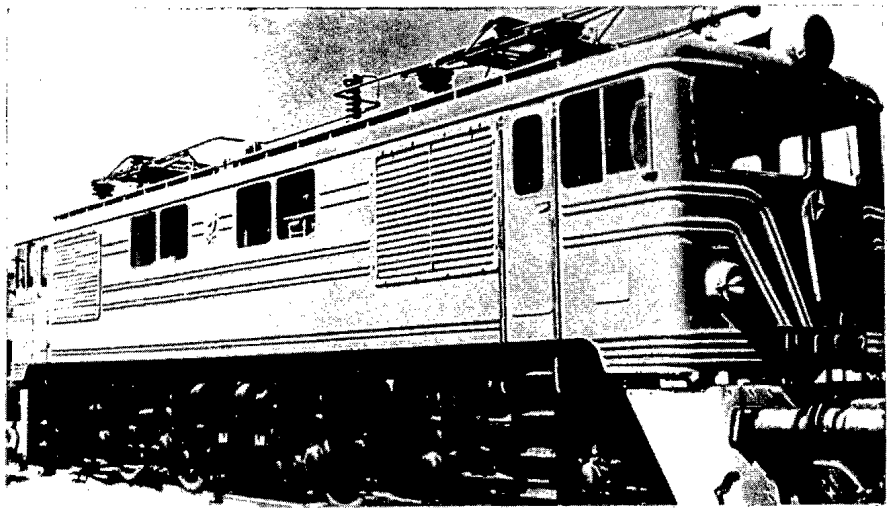

Figure 15. USSR: N-0 Alternating-Current Electric Passenger Locomotive, 1955. (Other views of this locomotive show that on the opposite side the two ventilating grills are replaced by windows.)

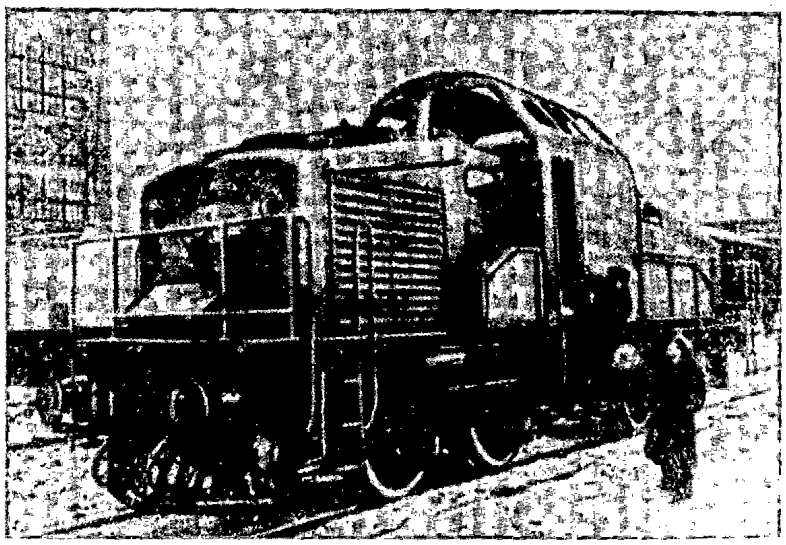

Figure 16. USSR: New TGv Diesel Switch Locomotive, 1957.

APPENDIX C

RELATIVE MERITS OF THE AC AND DC ELECTRIFICATION PROGRAMS IN THE USSR

At the end of 1956, when electrified railroad lines in the USSR totaled 6,325 km, the type and voltage of power used were as follows 316/:

Type of Current	Volts	Length of Line (Kilometers)	Percentage Distribution
Direct	3,000	5,674	89.7
Direct	1,500	503	7.9
Direct	825	11	0.2
Alternating, single-phase, 50-cycle	20,000	137	2.2
Total		6,325	100.0

The 3,000 volts DC is used on almost 90 percent of the railroads. Lines with 1,500 volts DC are found primarily in the Moscow suburban section. 317/ There is no information on where the 825 volts DC is used, but it is possible that it is in the Moscow area (see Appendix A). The 20,000 volts AC is installed experimentally on a line southeast of Moscow.

The AC line in operation uses single-phase, 50-cycle current of 20,000 volts. In the future this amount may be increased to 35,000 volts. It is hoped that AC operation will reduce the cost of electrification and increase the advantage of electric traction over other forms of traction on lines with high traffic density. The cost of power-supply installations is reduced with AC, and the usual distance between traction substations can be from 50 to 70 km compared with 20 to 25 km under the DC system.

Corresponding reductions will be possible in the number of service personnel and the volume of housing construction. Use of AC also has the possibility of combining traction substations with rayon powerplants, thereby further reducing costs. 318/ The use of AC also involves a considerably smaller increase in the cost of power in the event of heavier traffic, heavier trains, or higher train speeds. The most profitable train speed, in fact, is somewhat higher with AC than with DC. The higher voltage with AC reduces the expenditures of nonferrous metal for the contact network by two-thirds and also reduces power losses.

The average investment per kilometer of line for electrification with DC and AC in the USSR is shown in Table 25. The investment figures shown include electric power facilities, electric locomotives, and certain auxiliary facilities not necessarily related to electrification. These investment figures exclude the cost of lengthening yard and siding tracks and the construction of mechanized hump yards.

Table 25

Average Investment per Kilometer for Electrifying Railroad Lines in the USSR, a/ by Type of Current

	Direct Current		Alternating Current	
	Investment (Thousand Rubles)	Percentage Distribution	Investment (Thousand Rubles)	Percentage Distribution
Electric power facilities				
Traction substations	165.5	17.6	82.2	9.2
Contact network	216.5	23.1	163.5	18.4
External power supply	149.0	15.9	136.5	15.4
Total	531.0	56.6	382.2	43.0
Auxiliary facilities				
Signals, centralization, and blocking	22.1	2.3	39.4	4.4
Reconstruction of communications lines	28.0	3.0	116.3	13.1
Auxiliary installations and living quarters	25.8	2.7	22.8	2.6
Total	75.8	8.0	178.5	20.1
Electric locomotives	332.5	35.4	327.6	36.9
Grand total	939.3	100.0	888.3	100.0

a. 319/

APPENDIX D

METHODOLOGY

The methodologies employed in deriving estimates in this report are set forth in the text in connection with individual estimates. In general, these estimates were derived on the basis of calculations from Soviet data on percentage or absolute changes from years in which the data were reasonably firm and by projecting forward or backward or interpolating between known figures for 2 or more years. Unless there was reason to modify or reject them, Soviet data were accepted as being accurate. Estimates of costs were built up by combining Soviet statements and ORR estimates.

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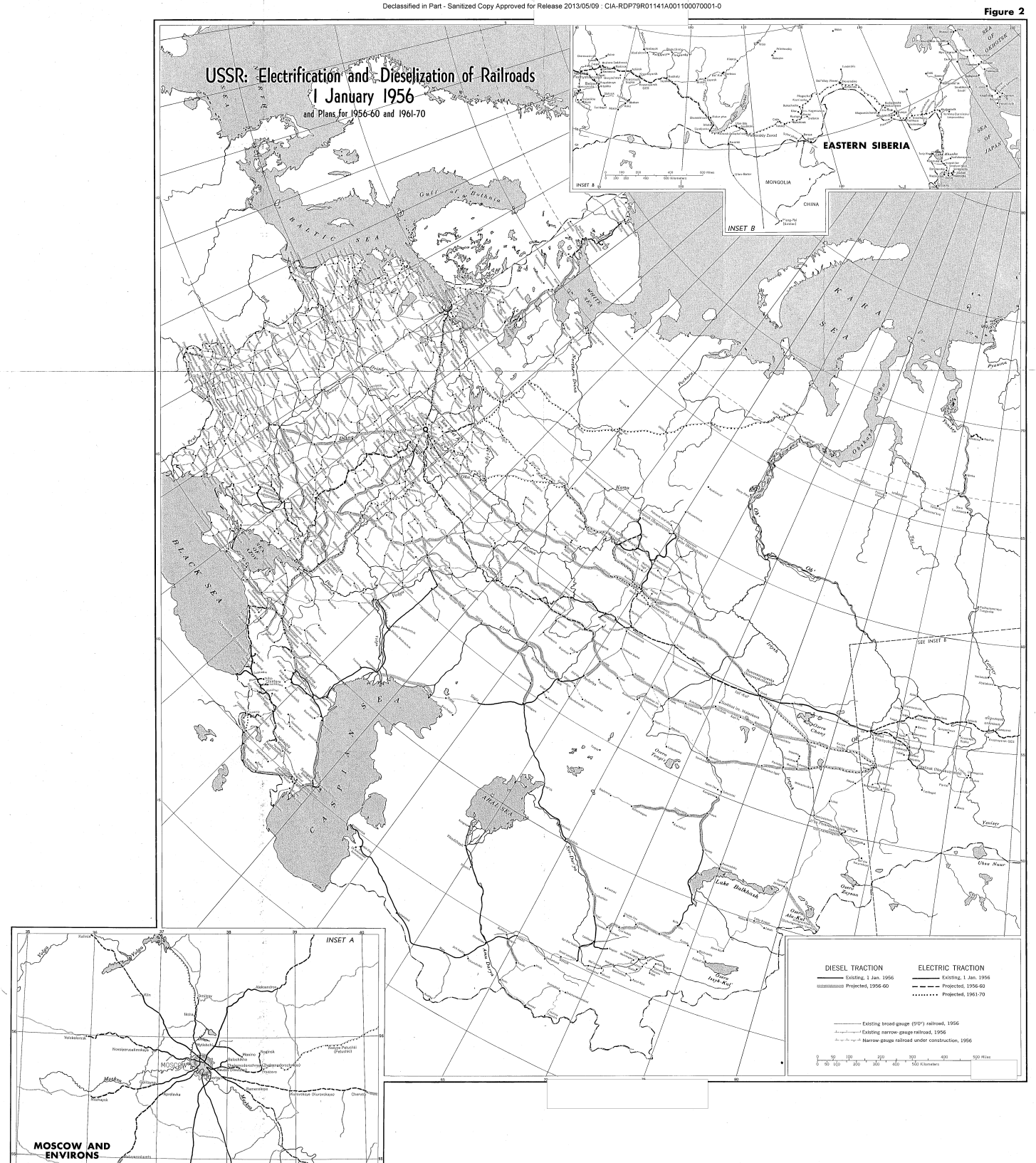
Figure 2



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